FINAL REPORT

OTIS WASTEWATER TREATMENT EVALUATION

SEPTEMBER 20, 1985

COMMONWEALTH OF MASSACHUSETTS
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CIVIL
REGISTERED
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9/20/85

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20 September 1985

Major Paul A. Brogna, MA ANG
Base Civil Engineer
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Otis Wastewater Treatment Evaluation
DAHA 19-85-C-0014

Dear Major Brogna:

In accordance with our contract dated January 18, 1985, we are pleased to submit herewith the report of our engineering evaluation of Otis Wastewater Treatment. The detailed results of our investigation are included in this volume and summarized in the Executive Summary.

We wish to express our appreciation to you and your staff for your cooperation and assistance in preparing this report.

We are available at your convenience to review this report with you and answer any questions you may have.

Very truly yours,

CAMP DRESSER & McKEE INC.

William E. Mackey Jr

William E. Mackey, Jr.
Vice President

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EXECUTIVE SUMMARY

BACKGROUND

For almost 50 years, the United States Military have operated a small wastewater treatment plant at what is now called the Otis Air National Guard Base at the Sandwich and Falmouth town lines.

Effluent from the plant, which in recent years has been operated at only about one-tenth of its design capacity of 3 million gallons per day (mgd), is discharged to sand filter beds, from which it percolates to the local groundwater at about 20-foot depth.

This facility has provided secondary treatment in accordance with the initial design standards. The recent detection of high levels of detergents and nitrogen in a nearby Town of Falmouth well at Ashumet, however, prompted the Massachusetts Division of Water Pollution Control to issue a discharge permit to the Massachusetts Air National Guard in October 1984. This permit stipulates that the plant must meet certain effluent standards that would improve the groundwater quality to drinking water standards.

As a result of the state's action, the Air National Guard engaged CDM to evaluate the Otis WWTP to determine whether it could be upgraded to meet the new standards and, if not, to evaluate some alternative measures to comply with the state-imposed standards.

EXISTING FACILITIES

The existing secondary treatment plant includes Imhoff tanks, high-rate trickling filters, final settling tanks, and eight sand filter beds. Sludge from the Imhoff tanks and final settling tanks is discharged to a lined sludge drying bed; dried sludge is carried to an onsite landfill for final disposal.

Facilities are generally in good order. In September 1983, facilities were rehabilitated, including an upgrading of the sand filter beds and sludge drying beds, installation of chlorination facilities, and replacement of faulty flow meters and discharge valves.

The plant produces a high quality secondary treatment effluent with average biochemical oxygen demand (BOD) and total suspended solids (SS) levels of 14 milligrams per liter (mg/L) and 12 mg/L, respectively. Nitrogen concentrations, however, exceed the state-imposed discharge permit limitations. It is unlikely that the existing facilities can meet the 10 mg/L total nitrogen limit in all of the onsite groundwater monitoring wells that were installed in 1983.

PROJECTED FUTURE SITUATION

Based on our discussions with ANG officials, we understand that, for the foreseeable future, Otis ANG Base activity will continue at about the same level as in the recent past. Therefore, we have projected future wastewater flows of about 0.3 mgd average daily flow and 0.5 maximum daily flow.

We expect that the "strength" (BOD and SS levels) of the raw wastewater will increase somewhat as the base personnel continue to take steps to reduce extraneous flows (e.g., infiltration of "clean" groundwater and inflow of stormwater into damaged pipes) into the sewer system.

ALTERNATIVES

Given that the existing facilities cannot meet the new discharge requirements, we have considered five alternatives that would succeed in meeting -- or obviating -- the requirements. They are as follows:

- Alternative 1 -- Pump raw wastewater to the new Falmouth municipal WWTP for treatment and disposal.

The existing plant would be abandoned; Otis wastewater would be pumped via a new pump station and 40,000-ft force main to the Town of Falmouth's WWTP for treatment and disposal. To treat the Otis flows, it would be necessary to increase the capacity of the Town's new WWTP.

- Alternative 1a -- Pump treated effluent to the Falmouth municipal WWTP site for disposal in additional infiltration basins to be constructed for the exclusive use of the ANG.

  Chlorinated effluent from the existing Otis WWTP would be pumped via a new pump station and 32,000-ft force main to three new infiltration basins to be built at the site of the Falmouth municipal WWTP.

- Alternative 2 -- Utilize the existing WWTP followed by land treatment.

  Effluent from the existing Otis WWTP would flow to one or more new, lined storage lagoons providing 36 million gallons of storage capacity. During the eight warmer months of the year, lagoon effluent would be chlorinated and pumped to some 60 acres of irrigation fields for land treatment by spray irrigation.

- Alternative 3 -- Construct a new biological nutrient removal treatment facility.

  A new 0.3-mgd WWTP facility would be built at Otis, providing advanced treatment by the so-called Bardenpho process -- biological removal of nitrogen -- prior to chlorination and discharge to the existing sand filter beds.

- Alternative 4 -- Pump treated wastewater to a northern base site for disposal.

Effluent from the existing Otis WWTP would be chlorinated and pumped via a new pumping station and 50,000-ft force main across base property to some 90,000 square feet of new infiltration basins located near the Cape Cod Canal.

The alternatives basically either provide higher levels of treatment (Alternatives 2 and 3) or shift the point of disposal to areas less likely to have adverse impact on sources of groundwater used for drinking water supply.

COSTS OF ALTERNATIVES

Estimated capital, annual operating and present worth costs for the five alternatives are as follows:

	Capital	Operating	Present Worth
Alternative 1	$4,765,000	$ 156,000	$5,800,000
Alternative 1A	$2,925,000	$ 265,000	$5,200,000
Alternative 2	$3,180,000	$ 272,000	$5,500,000
Alternative 3	$2,125,000	$ 320,000	$5,200,000
Alternative 4	$3,530,000	$ 265,000	$5,800,000

EVALUATION OF ALTERNATIVES

COST

Given the degree of accuracy that can be attached to cost estimates at this stage of concept development, there is no significant cost difference among the alternatives in terms of present worth.

EFFECTS ON GROUNDWATER

All of the alternatives produce a final effluent that can meet the state standards. The first four alternatives, however, leave open some questions about ultimate impacts on groundwater quality in Falmouth. It would in fact be necessary to conduct additional groundwater modeling to establish with confidence the likely impacts on groundwater of Alternatives 1 and 1A, to be certain that these alternatives wouldn't simply "move the problem" to a new area of town.

Alternative 4 has the advantage of restricting the area of degraded groundwater to federally owned land. As the treated effluent would flow with natural groundwater to the tidal waters of Cape Cod Canal, it would be necessary to determine the area impacted by groundwater studies.

CONSTRUCTION IMPACTS

Alternatives 1 and 1A, involving pumping of raw or treated wastewater to the Falmouth WWTP, would create substantial construction impacts on off base traffic and on Falmouth WWTP operations. Impacts of other alternatives are moderate, and restricted to the base.

EFFECTS ON OTIS WWTP OPERATIONS

Only Alternative 3 -- construction of a new, advanced WWTP at Otis -- would have a major effect on plant operations; careful planning and execution would be necessary to avoid temporary violations of interim discharge standards. Some existing treatment units would be taken offline during construction.

OPERATIONAL COMPLEXITY

Only Alternative 3 would pose a substantial additional challenge in terms of operational complexity. We have assumed that a qualified operator would be available to manage the facility; it might also be possible to contract the treatment services to a private company.

MUNICIPAL AGREEMENTS

Alternatives 1 and 1A would require agreements with the Town of Falmouth for allowing use of municipal facilities and for fair apportionment of costs.

SCHEDULE

The alternatives described above could be implemented in periods ranging from about 42 months for Alternative 2 to about 66 months for Alternatives 1 and 1A -- with completion dates of mid-1989 to mid-1991. None meets the implementation schedule of final design completed by October 1, 1986, imposed by the September 1984 Groundwater Discharge Permit.

RECOMMENDATION

The evaluation shows that no one alternative is clearly superior to all others; all have their benefits and adverse consequences.

One issue, however -- that of groundwater quality -- stands out in overriding importance. Looking at this issue alone, it is apparent that Alternatives 2 and 3 while meeting the letter of the state-issued discharge permit, will not restore the groundwater to the same quality as without a discharge. And, if the State imposes higher discharge standards in the future, a significant investment in additional facilities may be required. They cannot be considered the most desirable plans, therefore.

Alternatives 1, 1A, and 4 relocate the point of discharge to sites near the coastline, thus minimizing impacts on groundwater. Of these, Alternative 1 is least desirable because it abandons the Otis plant, imposes a requirement for plant expansion on the Town of Falmouth, and offers greater potential for impacting the water quality at Long Pond in Falmouth.

Both Alternative 1A and Alternative 4 are acceptable plans. Both will involve more groundwater studies and application for new or expanded Class 3 (nonpotable) groundwater areas. Both will require filing of an EIR/ENF. Both allow considerable flexibility with respect to flow variations.

Estimated initial capital costs for Alternative 1A are about $600,000 less than for Alternative 4. On the other hand, Alternative 1A may prove difficult to implement, if the Town objects to the plan.

We recommend that the Massachusetts Air National Guard pursue Alternative 1A as the recommended plan and consider Alternative 4 to be a logical and desirable "second choice" if it proves difficult to reach agreement with the Town of Falmouth.

1.0 INTRODUCTION

1.1 BACKGROUND

In 1936, a 0.9 million gallon per day (mgd) primary wastewater treatment plant (WWTP) was constructed to serve Camp Edwards. The plant was located at the southern boundary of the Base within the Town of Sandwich at the Falmouth town line. In 1941 a new 3.0-mgd secondary treatment plant at the same location was constructed to replace the primary plant. The secondary plant employs the trickling filter method of treatment and, as in the original primary plant, the effluent is discharged to sand filter beds. The plant was rehabilitated in 1983, but it uses essentially the same processes and equipment as the 1941 plant.

During World War II, up to 70,000 troops were trained at the base. Wastewater flows averaged between 1 and 2 mgd. From 1948 to 1973 the base was a major installation of the U.S. Air Force known as the Otis Air Force Base. Since 1973, the Otis facility has been used by the Massachusetts Air and Army National Guards and the U.S. Coast Guard; we refer to it in this report as the Otis Air National Guard Base (Otis ANG Base). Base population is now only about 2,500, with a peak summer training population of about 6,000. Wastewater flows to the plant are only about 0.3 mgd.

Wastewater effluent discharged to sand filter beds enters the local groundwater about 20 feet below the beds and travels southerly.

In 1976 the Town of Falmouth constructed a well at Ashumet, about one and one-half miles south of the Otis WWTP. After high levels of detergents were found in the well, the U.S. Geological Survey (USGS) and the Massachusetts Department of Environmental Quality Engineering (DEQE) initiated a study of groundwater conditions in the area. In 1982, the USGS published its findings -- the "Otis Plume Study." Researchers

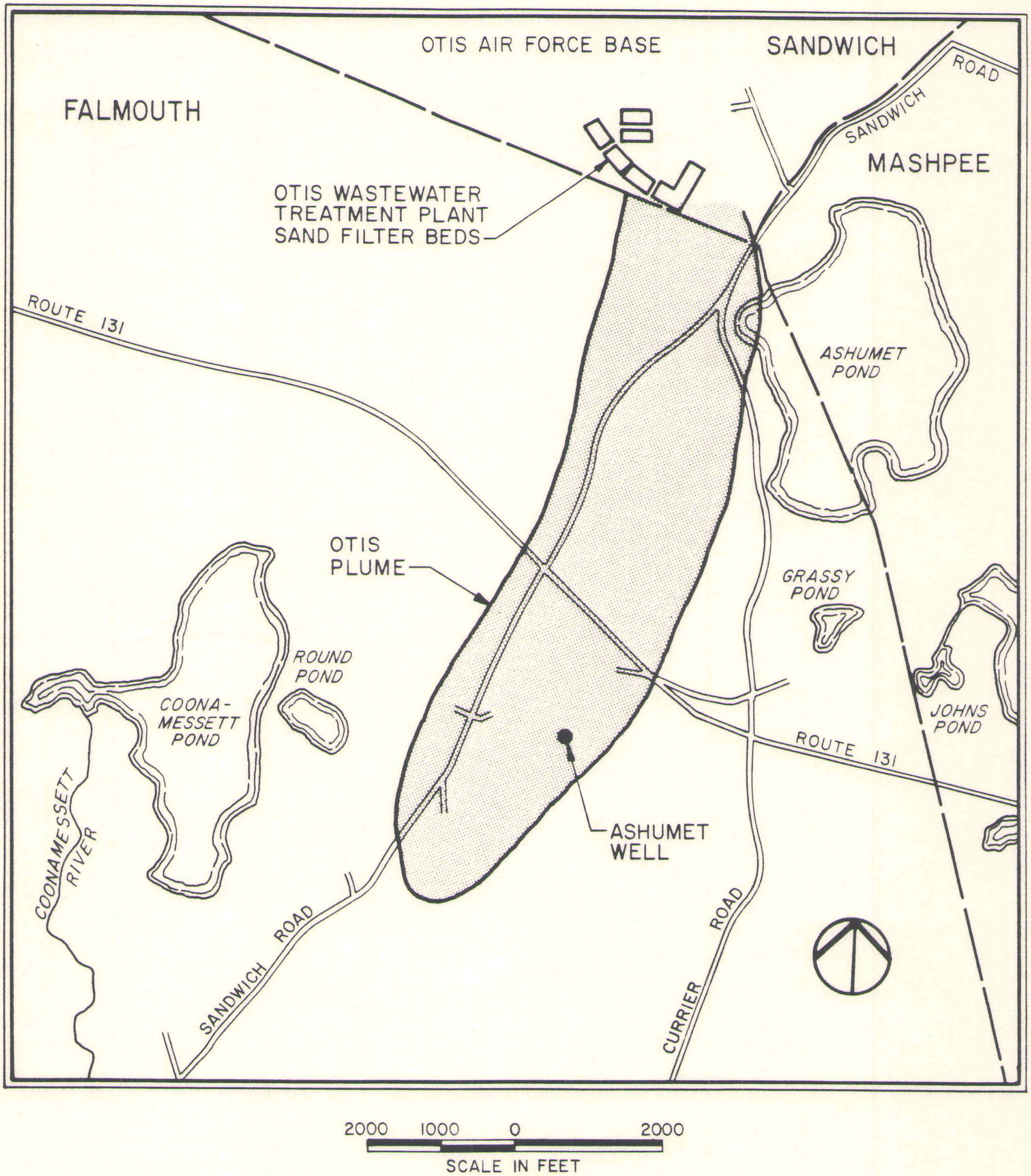
found that the Otis WWTP had created a plume of contaminated groundwater in the sand and gravel aquifer present in the northeast portion of Falmouth. The plume extends for about 11,000 feet south of the plant, is about 2,500 to 3,500 feet wide and is at a depth of about 30 to 90 feet below the ground surface.

A plan and cross section of the plume are shown in Figure 1-1 and 1-2. In the center of the plume, the detergent concentration is as high as 2.6 mg/L as MBAS (methylene blue active substances). The drinking water standard is 1.0 mg/L. Ammonia-nitrogen concentrations are as high as 20 mg/L. The total nitrogen standard for drinking water is 10 mg/L.

As a result of the USGS findings, the DEQE's Division of Water Pollution Control issued a discharge permit to the Massachusetts Air National Guard for the Otis plant in October, 1984. The discharge permit required the plant's effluent to meet certain standards that essentially would improve groundwater to drinking water standards.

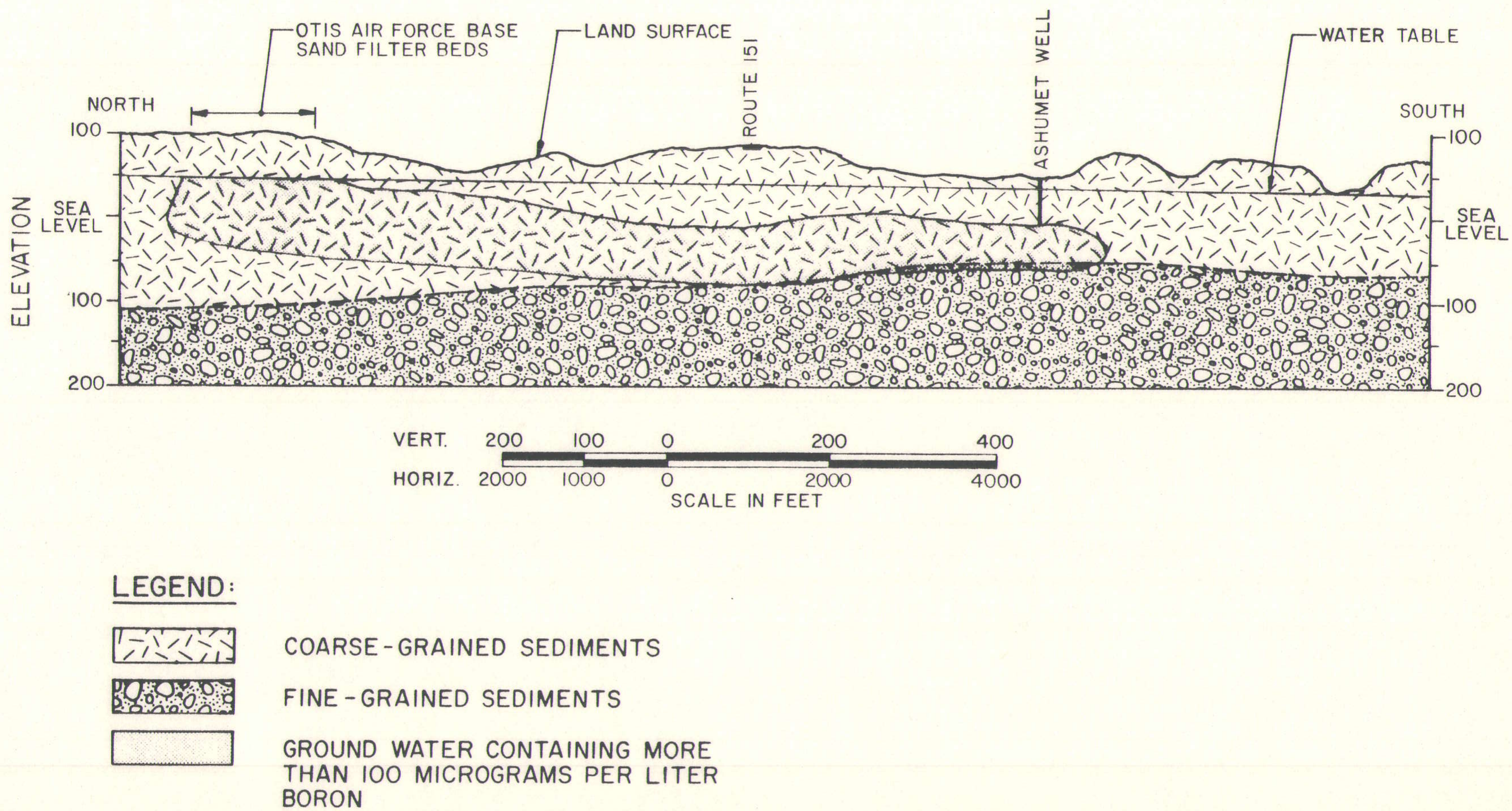
1.2 PURPOSE AND SCOPE OF WORK

The purpose of this report is to evaluate the Otis WWTP to determine if it is capable of producing an effluent that will meet the DEQE discharge permit requirements and other applicable Federal or State requirements. If the facility is not capable of meeting the standards then the following alternatives will be examined: (1) pump wastewater to Falmouth for treatment and/or disposal, (2) continue to operate the existing plant and construct a land treatment facility for effluent disposal, (3) construct a new advanced wastewater treatment plant employing biological nutrient removal with discharge to sand filter beds, and (4) pump treated wastewater to another location for disposal.



OTIS WASTEWATER TREATMENT EVALUATION

FIGURE I-I LOCATION OF OTIS PLUME
IN FALMOUTH, MASSACHUSETTS



OTIS WASTEWATER TREATMENT EVALUATION

FIGURE 1-2 CROSS SECTION OF OTIS PLUME

The scope of work developed by Camp Dresser & McKee Inc. (CDM) for the study includes the following tasks:

1. Develop work plan.
2. Information review and analysis.
3. Determine future wastewater flows and loadings.
4. Determine required effluent quality.
5. Formulation of feasible alternatives.
6. Develop costs of alternatives.
7. Evaluation of alternatives.
8. Rank alternatives and select a plan.
9. Implementation requirements.
10. Report preparation.
11. Project coordination and control.

1.3 PROJECT STAFFING AND ACKNOWLEDGMENTS

This report was prepared under the direction of Mr. William E. Mackey, Jr., Vice President. Project Manager was Mr. John F. Donovan. Project Engineer was Mr. Mario J. Marcaccio, assisted by Ms. Sara E. Sorkin, Mr. William B. Pepin, Mr. Robert A. Stoops, Ms. Janet M. Burns and Mr. John E. Bates.

This report on the Otis WWTP re-establishes CDM's service for the U.S. Military. In 1940, Mr. Herman G. Dresser, one of CDM's founding partners, designed the Otis secondary wastewater treatment plant.

Camp Dresser & McKee Inc. wishes to acknowledge the assistance of Otis Air National Guard staff: Major Paul A. Brogna, Base Civil Engineer, Mr. Earle P. Merritt, Jr., Mr. Normand Therriault and Mr. Richard E. Dugan; and staff of the Air National Guard Bureau, Andrews Air Force Base: Mr. Ronald Watson and Mr. Henry H. Lowman.

2.0 EXISTING WASTEWATER TREATMENT PLANT

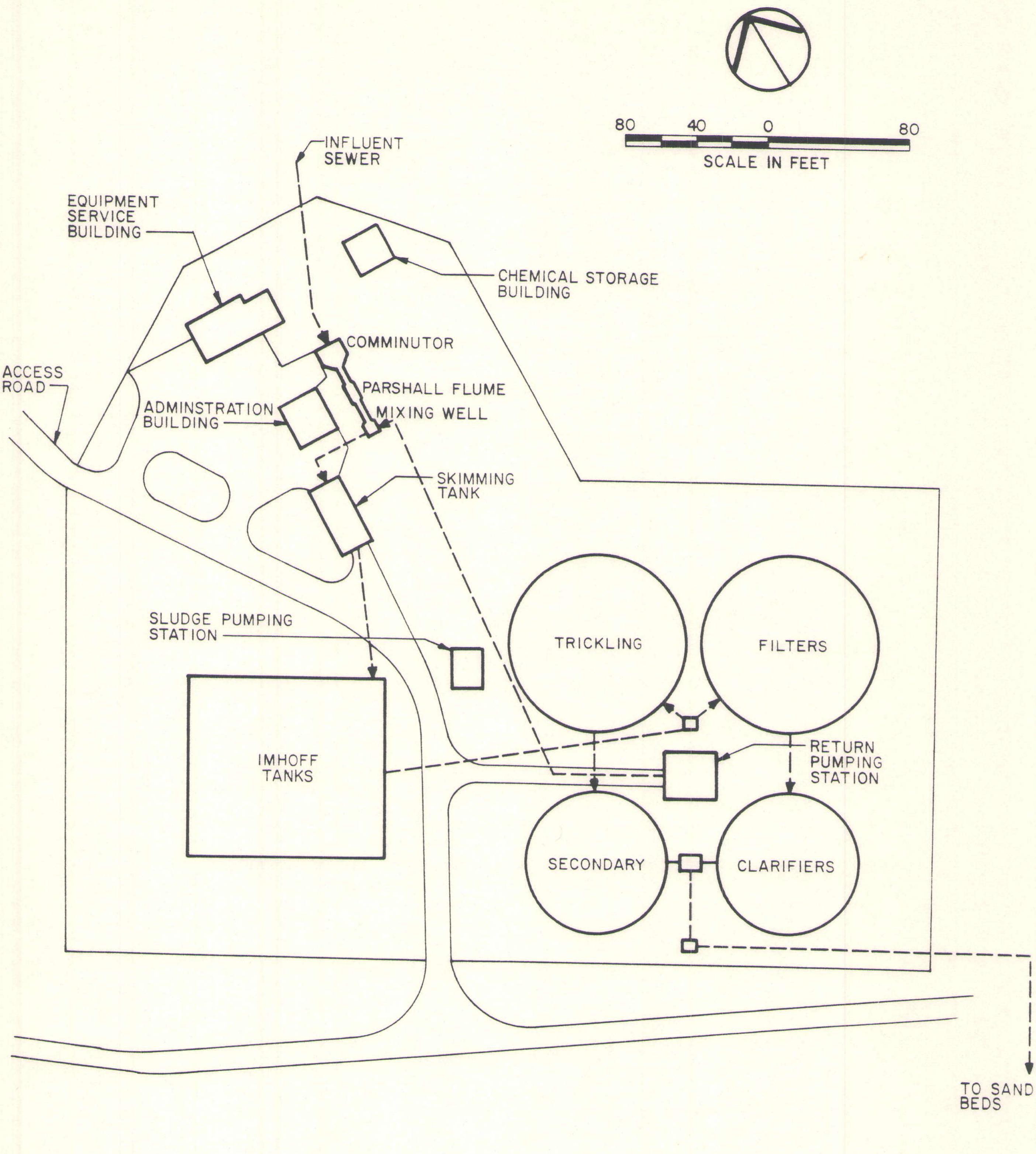
2.1 DESCRIPTION OF EXISTING FACILITIES

The Otis wastewater treatment plant is located in the southern portion of the Otis Air National Guard Base in the Town of Sandwich, MA near the Falmouth and Mashpee town boundaries.

The secondary wastewater treatment plant consists of a comminutor, a Parshall flume, a skimming tank, two Imhoff tanks, two high-rate trickling filters, two final clarifiers, chlorination equipment, eight sand filters (infiltration basins) and sludge drying beds. Figure 2-1 shows a plan view of the treatment plant excluding the sand filters and sludge drying beds which are located generally south of these facilities. The plant was designed for an average flow of 3.0 mgd but for 1984 only treated an average flow of 0.28 mgd, or 9 percent of design flow. Figure 2-2 shows a process flow diagram for the treatment plant.

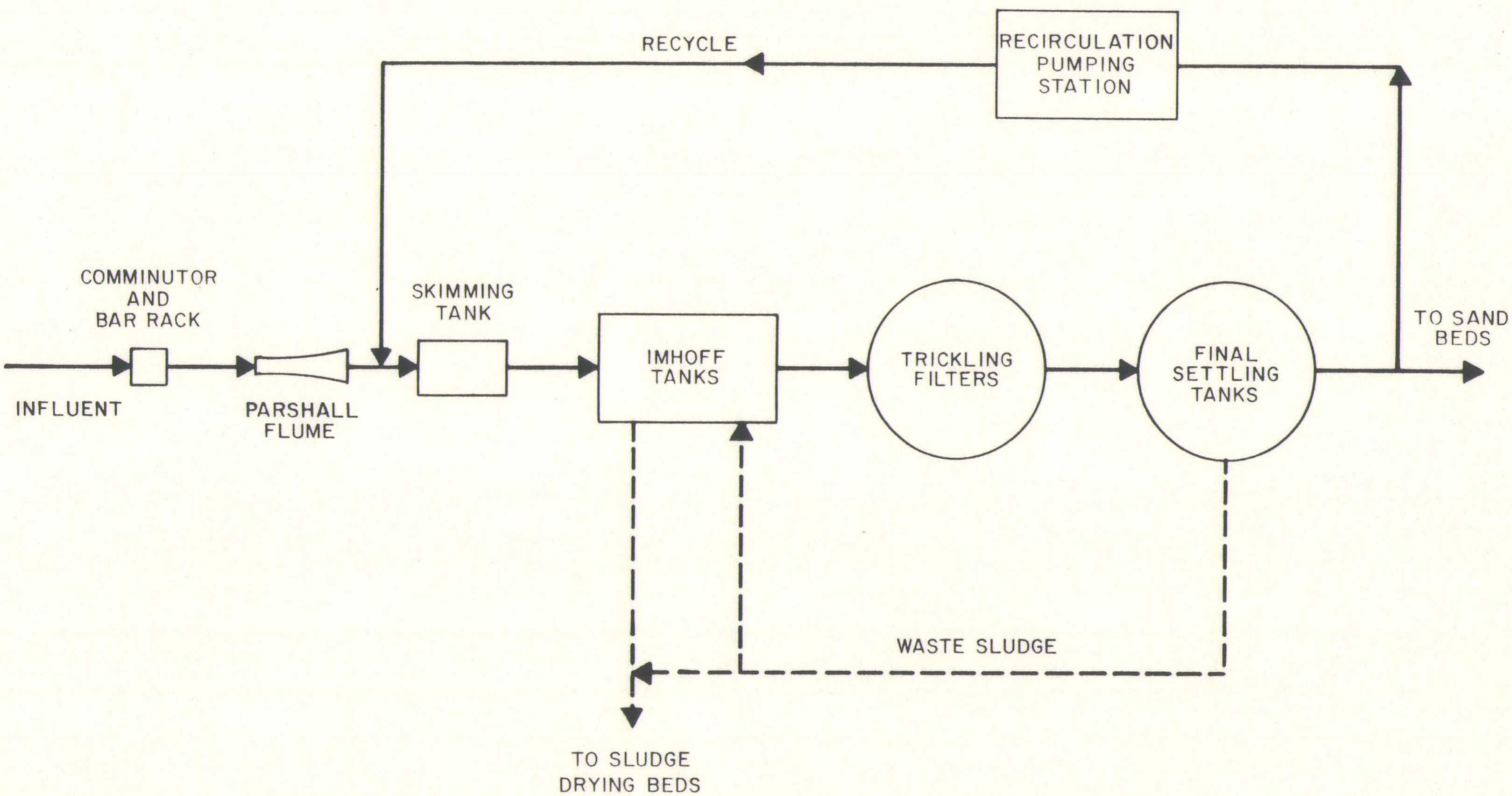
The wastewater enters the treatment plant at the headworks and passes through a comminutor where the large solids are shredded. A bypass channel with a bar rack is provided for times when the comminutor malfunctions or undergoes maintenance. The wastewater then flows through a 9-inch Parshall flume for flow measurement before being mixed with the treated recycle. The combined flow then passes to a 28,600-gallon grease skimming flocculation tank. Compressed air at a rate of approximately 155 cubic feet per minute (cfm) is blown into the tank to aid in the removal of the oil, grease and other floatable material.

The wastewater then flows into one of the two Imhoff tanks where the solids settle out and undergo digestion in the bottom part of the tank. Each tank is 90 feet long by 50 feet wide with a sedimentation capacity of 37,150 cubic feet. The effluent from the Imhoff tank flows into one



OTIS WASTEWATER TREATMENT EVALUATION

FIGURE 2-1 PLAN VIEW OF WASTEWATER PLANT



OTIS WASTEWATER TREATMENT EVALUATION

FIGURE 2-2 PROCESS FLOW DIAGRAM

of the two high-rate trickling filters. Each trickling filter is 100 feet in diameter and consists of a rock media 3 feet deep, providing 23,550 cubic feet of filter media volume. The wastewater exits the tricking filter and flows into one of the two final settling tanks. The settling tanks are each 74 feet in diameter with a sidewater depth of 8 feet, providing a volume of 281,000 gallons. Each trickling filter is paired up with one final settling tank and piped to allow the operation of one or both of the trickling filter/final settling tank combinations. Under normal operation, only one of the trickling filter/final settling tank combinations is used. Every six months, the alternate set of trickling filter/final settling tank is brought on-line.

The effluent from the final settling tank then flows by gravity to four acres of sand filter beds. The plant was originally constructed with 24 beds each with a 22,000-square-foot surface area. However, in September, 1983, eight of the beds were reconstructed, and these are the only ones used. The flow is discharged to the beds, alternating automatically from one bed to the next every three hours.

The renovation in September 1983 included the addition of chlorination facilities, but not the addition of a chlorine contact tank. Chlorine is not added at the present time. There appears to be sufficient contact time at average current flows for disinfection in the distribution lines to the sand filters, but mixing in the lines might not be adequate for effective disinfection.

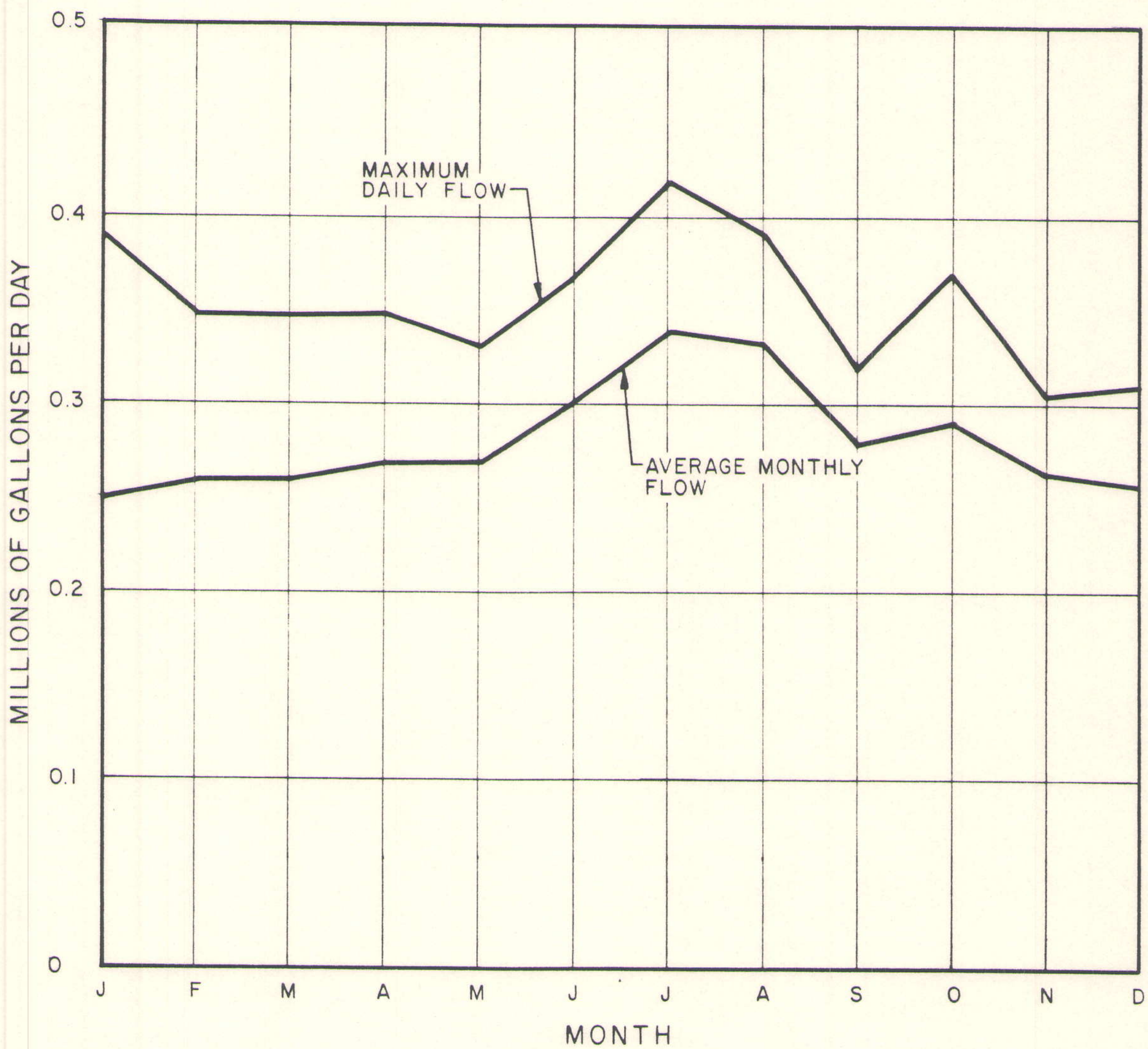
A portion of the effluent from the final settling tanks is recirculated to a mixing well at the headworks of the plant located just after the Parshall flume. The recycle is necessary to ensure that each of the treatment components is being loaded at the proper hydraulic rate. The recirculation flow is controlled by three pumps rated at 1,000, 2,000, and 3,000 gallons per minute (gpm) each. The 2,000-gpm pump is normally used. The average recycle rate during 1984 was about 1,600 gpm.

The waste sludge from the final settling tanks can be pumped back to the Imhoff tanks or directly to the sludge drying beds. Normally, sludge is wasted only every six months when final settling tanks are changed. The sludge from the Imhoff tank is drawn off directly to the sludge drying bed. The original plant consisted of 22 sludge drying beds. Under the modifications in 1983, however, two of the beds, each with a surface area of 4,500 square feet, were reconstructed. One of the reconstructed beds is used as a sludge drying bed. Its leachate is collected and discharged to the other lined bed, which serves as a leachate collection pond with a 50,000-gallon capacity. The collected leachate is allowed to evaporate or may be pumped to the Imhoff tank. The dried sludge is hauled to the sanitary landfill on base.

2.2 PLANT PERFORMANCE

As mentioned previously, the plant was modified in September 1983. The flow meters, and discharge valves were replaced during this reconstruction. The reliability of the flow records prior to the modifications is questionable, due to the malfunctioning flow meter and high inflow caused by open drainpipes at demolished buildings. These open drains have been capped, and the inflow has now been brought under control. For these reasons, we used only the 1984 plant records.

The 1984 flow records are shown graphically on Figure 2-3. The lower curve represents the average monthly flow and ranges from a low of 0.25 mgd in January to a high of 0.33 mgd in July. The upper curve represents the maximum daily flow for each month. The maximum daily flow ranges from a low of 0.31 in November to a high of 0.42 in July. Both of the curves show a definite increase in flow during the summer months when the population of the Base increases due to the influx of the National Guard troops for training. The average daily flow for 1984 was 0.28 mgd with a recirculation ratio of 8.3 for a total flow including recycle of 2.6 mgd. The plant was designed for an average daily flow of 3.0 mgd with a recirculation ratio of 1.5 for a total flow



OTIS WASTEWATER TREATMENT EVALUATION

FIGURE 2-3 1984 FLOWS TO PLANT

including recycle of 7.5 mgd. Therefore, the plant is operating at an inflow of 9 percent of the design average flow and a total recycle flow of 35 percent of the design recycle flow.

Table 2-1 shows a unit-by-unit comparison of the 1984 performance to the original design parameters. As shown, the influent biochemical oxygen demand (BOD) is typical of a weak strength domestic wastewater of 118 mg/L for a total load of 275 lbs/day, well below the design load of 5,254 lbs/day.

The grease skimming flocculation tank is functioning without any problems and providing a detention time of 16 minutes with recycle or 2.8 times the original design values.

The Imhoff tank is removing 40 percent of the BOD. This value, which is higher than the original design value of 30 percent removal, results from the high detention time caused by the low flows. The overflow rate with recycle of 580 gpd/sq.ft. falls within the recommended loading of 500-700 gpd/sq.ft.

The trickling filter has an acceptable hydraulic loading rate with recycle of 330 gpd/sq.ft. However, the BOD loading with recycle of 13.8 lb/d/cu.ft. is below the recommended values of 25-300 lb/d/cu.ft. This may be one reason why the trickling filters do not nitrify the wastewater.

The final settling tanks have a detention time with recycle of 2.6 hours, or nearly one hour more than the design detention time of 1.8 hours. The overflow rate with recycle of 604 gpd/sq.ft. is within recommended loadings of 500-700 gpd/sq.ft. As noted earlier, sludge is not withdrawn on a regular schedule from the final settling tanks.

Overall, the existing plant is producing a high quality effluent with a BOD of 14 mg/L and total suspended solids (SS) of 12 mg/L. This represents an 88 percent and 86 percent removal of BOD and SS, respectively.

TABLE 2-1

OTIS WASTEWATER TREATMENT PLANT
COMPARISON OF 1984 PERFORMANCE TO
ORIGINAL DESIGN CRITERIA

	1984 Performance	Original Design
FLOW (MGD)		
Average	0.28	3.0
Maximum	0.42	6.0
Recirculation ratio at average flow	8.3	1.5
Total flow including recycle at average	2.6	7.5
BOD		
Average, mg/L	118	210
Average lb/d	275	5,254
GREASE SKIMMING FLOCCULATION TANK		
No. of units	1	1
Length, ft	32.5	32.5
Width, ft	17	17
Depth, ft	10	10
Volume, gal	28,600	28,600
Detention period (w/o recycle), min	147	14
Blower capacity, cfm	155	155
Detention period (w/recycle), min	16	5.6
IMHOFF TANK		
No. of units	1	2
Length, ft	90	90
Width each tank, ft	50	50
Total area per tank, sq ft	4,500	4,500
Overflow rate (w/o recycle), gal/d/sq ft	62	333
Overflow rate (w/recycle), gal/d/sq ft	580	832
Sedimentation capacity, cu ft	37,150	74,300
Detention time (w/o recycle), hr	24	4.5
Detention time (w/recycle), hr	2.6	1.8
Digestion capacity, cu ft	69,200	138,400
BOD removal, %	40	30
TRICKLING FILTERS		
No. of units	1	2
Diameter, ft	100	100
Total surface area, sq ft	7,850	15,700
Depth of filter media, ft	3	3
Volume of filter media, cu ft	23,550	47,100
Hydraulic loading rate (w/o recycle), gal/d/sq ft	36	190

TABLE 2-1
(continued)

	1984 Performance	Original Design
Hydraulic loading rate (w/recycle), gal/d/sq ft	330	475
TRICKLING FILTERS (continued)		
BOD loading (w/o recycle), lb/d/1,000 cu ft	7	78
BOD loading (w/recycle), lb/d/1,000 cu ft	13.8	95
SECONDARY SETTLING TANKS		
No. of units	1	2
Diameter, ft	74	74
Sidewater depth, ft	8	8
Total volume, gal	281,000	562,000
Detention time (w/o recycle), hr	24	4.5
Detention time (w/recycle), hr	2.6	1.8
Total surface area, sq ft	4,300	8,600
Overflow rate (w/o recycle), gal/d/sq ft	65	350
Overflow rate (w/recycle), gal/d/sq ft	604	870
RECIRCULATION PUMPS		
No. of units (in service)	1	3
Capacity No. 1, gpm	-	1,000
Capacity No. 2, gpm	2,000	2,000
Capacity No. 3, gpm	-	3,000
SAND FILTER BEDS		
No. of units	-	24
Area each, sq ft	22,000	22,000
Loading rate at average, gal/d/sq ft	-	5.6
No. of units in operation (Beds 5-12)	8	8
Loading rate at average, gal/d/sq ft	1.6	3.0
SLUDGE DRYING BEDS		
No. of units	1	22
Total area, sq ft	4,800	92,000

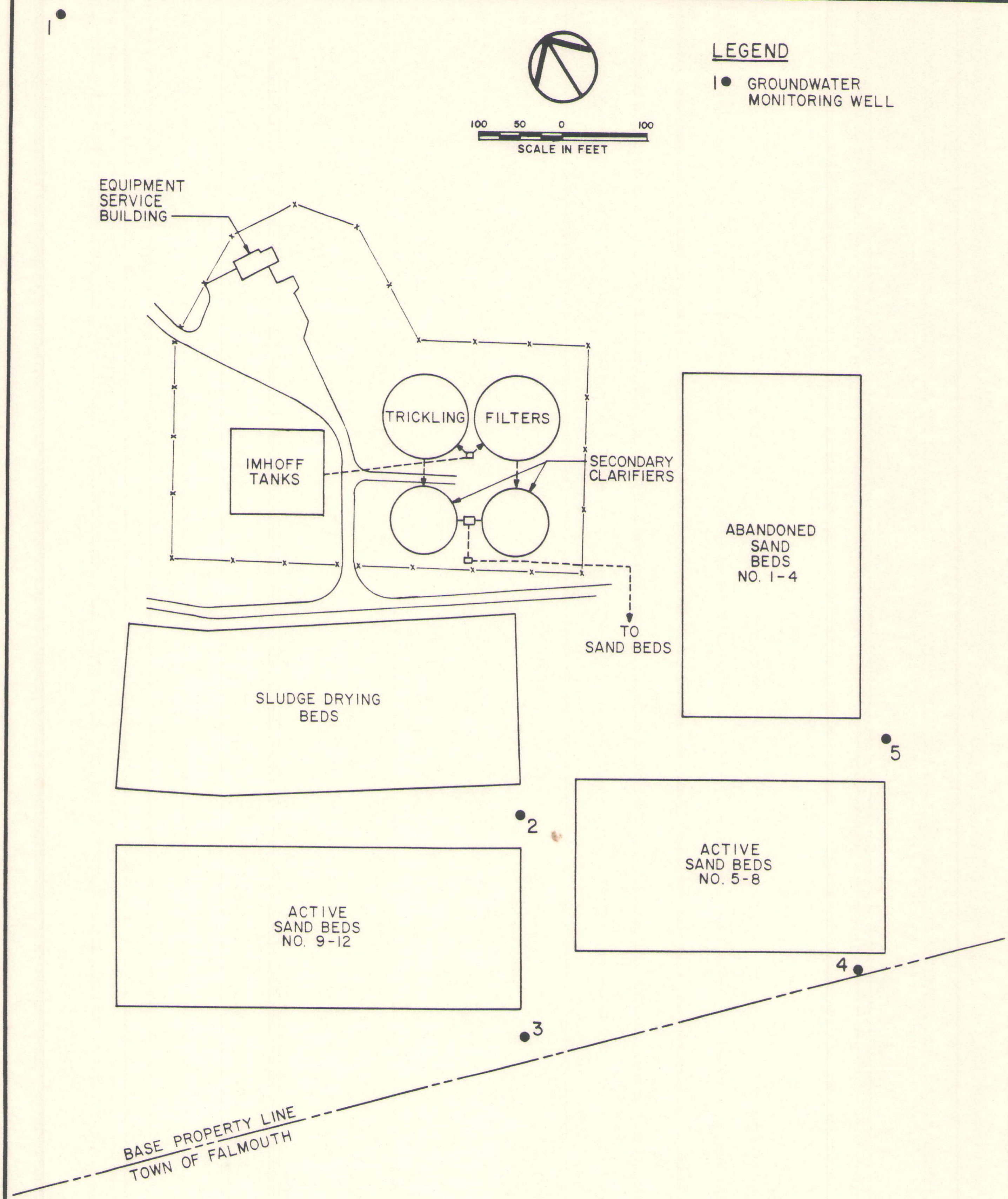
After dosing to sand filter beds the wastewater effluent undergoes further treatment in the soil. To ascertain the degree of improvement, groundwater monitoring wells were installed as part of a Memorandum of Understanding between EPA and the U.S. Air Force in 1983. Figure 2-4 shows the location of the five monitoring wells. The general groundwater flow in the area is north to south. Therefore, Well No. 1 is an upgradient or background water quality indicator, and the remaining wells are downgradient wells.

The major constituent of concern is nitrogen, since no nitrogen removal is practiced at the plant. Tables 2-2 through 2-6 show nitrogen concentrations in the monitoring wells for the period April 1984 to May 1985. Concentrations are measured at two depths; one sample at about elevation 50, which is the top of the groundwater surface, and a second sample about 20 feet deeper. During the summer of 1984, effluent disposal to sand filter beds No. 1-4 was stopped. Only the rehabilitated beds No. 5-12 have been used since.

A limit of 10 mg/L nitrate-nitrogen concentration for a public water supplies has been established by the EPA. Readings from well No. 1 have shown total nitrogen levels of 0.8 to 1.7 mg/L, well below the standard. Since the new filter beds have been in operation, wells No. 2 and No. 5 have shown total nitrogen concentrations generally decreasing with values below 10 mg/L. This reflects the abandoning of beds No. 1-4 and the installation of a liner below the sludge drying beds.

Well No. 4 has only exceeded the 10 mg/L standard only once since the new beds became operative. Well No. 3 has shown an increase in total nitrogen concentrations since the summer of 1984. Since January 1985 total nitrogen has averaged about 11 mg/L with a peak of 14.4 mg/L.

Groundwater quality data show that nitrogen concentrations exceed the State discharge permit standards. With the present method of secondary treatment, it is unlikely that standards can be met in the monitoring wells. A discussion of the discharge permit requirements and alternatives for effluent disposal are presented in Chapters 3 and 4.



OTIS WASTEWATER TREATMENT EVALUATION

FIG. 2-4 PLAN SHOWING LOCATION OF GROUNDWATER MONITORING WELLS

TABLE 2-2

NITROGEN CONCENTRATIONS AT
MONITORING WELL NO. W-1

Date	Sample El. (ft)	NH_3-N (mg/L)	NO_2-N (mg/L)	NO_3-N (mg/L)	Total N (mg/L)
04/84	49	0.28	0.01	0.87	1.2
05/84	49	0.12	0.01	0.99	1.1
06/84	49	0.19	0.01	0.63	0.8
07/84	49	0.21	0.01	0.99	1.2
08/84	49	0.39	-	0.50	0.9
09/84	49	0.20	-	0.62	0.8
10/84	49	0.03	-	1.04*	1.1
11/84	49	-	-	1.20*	1.2
12/84	49	-	-	1.20*	1.2
01/85	49	0.01*	-	1.12	1.1
02/85	49	0.01*	-	0.86	0.9
03/85	49	0.01*	-	0.89	0.9
04/85	49	0.03*	-	0.95	1.0
05/85	49	0.03*	-	0.85	0.9
04/84	31	0.15	0.01	0.87	1.0
05/84	31	0.15	0.01	1.18	1.3
06/84	31	0.61	0.01	1.07	1.7
07/84	31	0.22	0.01	0.82	1.1
08/84	31	0.60	-	0.64	1.2
09/84	31	0.15	-	0.66	0.8
10/84	31	-------	Pump Broken	-------	-------
11/84	31	0.04*	-	1.20*	1.2
12/84	31	0.028*	-	1.06*	1.1
01/85	31	0.01*	-	0.99*	1.0
02/85	31	0.01*	-	0.97*	1.0
03/85	31	0.01*	-	1.31*	1.3
04/85	31	0.03*	-	1.15*	1.2
05/85	31	0.01*	-	1.40*	1.4

* Preservative added to these test samples

TABLE 2-3

NITROGEN CONCENTRATIONS AT
MONITORING WELL NO. W-2

Date	Sample El. (ft)	NH_3-N (mg/L)	NO_2-N (mg/L)	NO_3-N (mg/L)	Total N (mg/L)
04/84	49	0.07	0.01	6.59	6.7
05/84	49	0.23	0.01	8.00	8.2
06/84	49	0.19	0.01	7.47	7.7
07/84	49	0.18	0.01	6.53	6.7
08/84	49	0.21	-	5.36	5.6
09/84	49	0.08	-	3.69	3.8
10/84	49	-	-	3.50*	3.5
11/84	49	-	-	1.42*	1.4
12/84	49	-	-	0.70*	0.7
01/85	48	0.03*	-	6.59*	6.6
02/85	48	0.01*	-	2.98*	3.0
05/85	48	0.04*	-	3.34*	3.4
04/84	31	0.24	0.01	5.61	5.9
05/84	31	0.20	0.01	6.50	6.7
06/84	31	0.35	0.01	7.20	7.6
07/84	31	0.27	0.01	6.30	6.6
08/84	31	0.55	-	5.11	5.7
09/84	31	0.83	-	2.32	3.2
10/84	31	0.32*	-	1.67*	1.8
12/84	31	0.17*	-	0.73*	0.90
01/85	30	0.06*	-	4.61*	4.7
02/85	30	0.03*	-	2.92*	3.0
03/85	30	0.04*	-	0.79*	0.8
04/85	30	0.06*	-	1.81*	1.9
05/85	30	0.05*	-	2.57*	2.5

* Preservative added to these test samples

TABLE 2-4

NITROGEN CONCENTRATIONS AT
MONITORING WELL NO. W-3

Date	Sample El. (ft)	NH_3-N (mg/L)	NO_2-N (mg/L)	NO_3-N (mg/L)	Total N (mg/L)
04/84	49	0.24	0.03	0.61	0.9
05/84	49	1.20	0.02	1.53	2.7
06/84	49	3.55	0.02	0.89	4.5
07/84	49	8.34	0.14	1.27	9.8
08/84	49	8.90	-	1.00	9.9
09/84	49	10.95	-	0.81	11.8
10/84	48	4.76*	-	2.75*	7.5
11/84	49	-	-	2.32*	2.3
12/84	49	-	-	1.01*	1.0
01/85	48	4.30*	-	6.10*	10.4
02/85	48	5.70*	-	7.03*	12.7
03/85	48	6.00*	-	1.12*	7.1
04/85	48	4.40*	-	9.37*	13.7
04/84	31	0.32	0.01	0.32	0.6
05/84	31	2.10	0.01	0.45	2.6
06/84	31	4.10	0.01	0.43	4.5
07/84	31	10.77	0.05	4.00	14.8
08/84	31	13.60	-	2.88	16.5
09/84	31	13.90	-	0.86	14.8
10/84	31	6.71*	-	0.16*	6.9
11/84	31	5.40*	-	1.40*	6.8
12/84	31	3.75*	-	1.01*	4.8
01/85	30	5.81*	-	4.27*	10.1
02/85	30	5.20*	-	5.76*	11.0
03/85	30	5.05*	-	1.13*	6.2
04/85	30	6.80*	-	5.64*	12.4
05/84	30	6.00*	-	8.35*	14.4

* Preservative added to these test samples

TABLE 2-5

NITROGEN CONCENTRATIONS AT
MONITORING WELL NO. W-4

Date	Sample El. (ft)	NH_3-N (mg/L)	NO_2-N (mg/L)	NO_3-N (mg/L)	Total N (mg/L)
04/84	49	0.82	0.05	2.08	2.9
05/84	49	0.15	0.17	3.08	3.4
06/84	49	0.53	0.11	3.83	4.5
07/84	49	1.00	0.11	3.49	4.6
08/84	49	0.10	-	4.03	4.1
09/84	49	0.08*	-	8.28*	8.4
10/84	49	0.04	-	12.55*	12.6
11/84	49	-	-	5.70*	5.7
12/84	49	-	-	1.03	1.0
01/85	47	0.94	-	6.89	7.8
02/85	47	1.32	-	1.63	3.0
03/85	47	1.50	-	0.14	1.6
04/85	47	0.62	-	1.02	1.6
05/85	47	0.86	-	1.63	2.5
04/84	31	2.43	0.01	0.18	2.6
05/84	31	1.70	0.02	0.41	2.1
06/84	31	2.10	0.03	0.61	2.7
07/84	31	2.80	0.06	1.53	4.4
08/84	31	1.05	-	2.70	3.8
09/84	31	0.88*	-	4.93*	5.8
10/84	31	1.16*	-	6.95*	8.1
11/84	31	1.85*	-	2.62*	4.5
12/84	31	1.37	-	0.80	2.2
01/85	29	1.61*	-	5.06*	6.6
02/85	29	1.45*	-	1.38*	2.8
03/85	29	1.40*	-	0.26*	1.7
04/85	29	0.78	-	1.08*	1.9
05/85	29	0.78	-	1.54*	2.3

* Preservative added to these test samples

TABLE 2-6

NITROGEN CONCENTRATIONS AT
MONITORING WELL NO. W-5

Date	Sample El. (ft)	NH_3-N (mg/L)	NO_2-N (mg/L)	NO_3-N (mg/L)	Total N (mg/L)
04/84	49	0.22	0.03	9.02	9.3
05/84	49	1.63	0.04	9.93	11.6
06/84	49	1.36	0.04	5.99	7.4
07/84	49	0.55	0.02	10.75	11.3
08/84	49	0.06	-	8.76	8.8
09/84	49	0.17	-	4.06	4.2
10/84	49	0.11*	-	0.86	1.0
11/84	49	-	-	0.70*	0.7
12/84	49	-	-	1.06*	1.1
01/85	48	0.01*	-	0.91*	1.0
02/85	48	0.01*	-	1.51*	1.6
03/85	48	0.06*	-	3.84*	3.9
04/85	48	0.06*	-	2.80*	2.9
05/85	48	0.04*	-	3.52*	3.6
04/84	31	0.70	0.02	7.35	8.1
05/84	31	2.90	0.02	9.05	12.0
06/84	31	1.79	0.04	7.41	9.3
07/84	31	0.81	0.28	9.71	10.8
08/84	31	0.21	-	9.22	9.4
09/84	31	0.36	-	4.10	4.4
10/84	31	0.54*	-	1.89*	2.3
11/84	31	0.91*	-	1.70*	2.6
12/84	31	0.42*	-	0.66*	1.1
01/85	30	0.51*	-	1.42*	1.9
02/85	30	0.47*	-	2.75*	3.2
03/85	30	0.37*	-	1.07*	1.4
04/85	30	0.35*	-	4.40*	4.8
05/85	30	0.23*	-	3.87*	4.1

* Preservative added to these test samples

3.0 WASTEWATER FLOWS AND LOADINGS

3.1 WASTEWATER FLOW PROJECTIONS

As shown in Section 2, the average annual flow to the Otis WWTP for 1984 was about 0.28 mgd. This volume is considerably lower than the 0.5 mgd average flows typically recorded a few years ago but it is now believed that the plant flow meter used before October 1983 was in error. A new flow meter installed in 1983 was checked and verified in March 1984 by a team from the USAF Occupational and Environmental Health Laboratory (OEHL), who found average flow to be about 0.23 mgd.

Another factor in the apparent reduction of flows recorded during the last several years can be attributed to a reduction of non-sewage inflow to the sewer system. A portion of the 1983 rehabilitation contract involved sealing of open drain lines from demolished buildings, which would have eliminated at least a portion of system inflow.

In order to estimate future wastewater flows, Base officials were contacted. Efforts are underway to upgrade base faciities as summarized in the Camp Edwards Master Plan. However, no major base expansion is planned and Base officials concluded that future wastewater flows will remain in the same range as that experienced in the last two years. The alternatives presented later in this report are designed to handle an average annual daily flow of about 0.3 mgd and a maximum daily flow of 0.5 mgd. In Chapter 6, the affect of increased plant flows on the sizing, cost and analysis of alternatives will be discussed.

3.2 WASTEWATER LOADINGS PROJECTIONS

During March 1985, sampling was conducted on two occasions to determine the basis for wastewater loading projections. Sampling included BOD and SS as well as constituents not normally sampled on a routine basis. Table 3-1 shows the test results.

TABLE 3-1

TEST RESULTS OF
INFLUENT AND EFFLUENT FOR OTIS WWTP
(all results in mg/L except where noted)

Test Type	Influent 03/12/85	Influent 03/19/85	Effluent 03/12/85	Effluent 03/19/85
Biological Oxygen Demand	115	88	16	18
Total Suspended Solids	65	80	16	21
Ammonia as N	25.8	20.2	19.0	17.0
Nitrate as N	<0.1	<0.1	1.65	1.42
Total Kjeldahl Nitrogen	33.1	24.9	20.6	20.9
Total Phosphate as P	7.8	7.2	7.0	7.8
Oil & Grease	-	-	15.6	11.3
Sodium	39.6	40.2	86.4	42.8
Total Coliform MPN/100 ml	-	-	>24,000	1,600,000

BOD concentrations averaged 101 mg/L, about 15 percent lower than the 1984 average of 118 mg/L. A BOD design concentration of 125 mg/L was selected for this study. More extensive sampling and data analysis would be undertaken during design of plant improvements for selection of a final BOD concentration.

SS concentrations averaged only 73 mg/L for the two tests. During 1984 monthly averages ranged between 67 to 110 mg/L. This degree of fluctuation reflects a high amount of infiltration in the sewer system. A SS design concentration of 125 mg/L was selected for this study to accommodate any future efforts to reduce sewer system infiltration (such efforts, by reducing non-sewage flows, tend to increase the "strength" of the raw wastewater).

Nitrogen sampling showed that incoming ammonia is only slightly oxidized to nitrate nitrogen. This data supports earlier work by the USAF Occupational and Environmental Health Laboratory in 1984 which also showed poor nitrification (oxidation of ammonia). Based on the sampling program and on concentrations at other wastewater treatment plants, a total nitrogen concentration of 30 mg/L was selected.

Phosphorus concentrations of about 8 mg/L can be expected in the wastewater influent. Total coliform concentrations in the effluent were high because at present the plant effluent is not chlorinated.

3.3 DISCHARGE PERMIT REQUIREMENTS

In September 1984, a groundwater discharge permit was issued for the Otis WWTP. Table 3-2 shows the discharge limitations shown in Special Conditions No. 1 of the permit. The standards are imposed at the distribution structure, prior to discharge of effluent to the sand filter beds.

TABLE 3-2

OTIS GROUNDWATER DISCHARGE PERMIT

Parameter	Limit (mg/L except as noted)
Flow, mgd	0.8
BOD, 5-day, 20°C	30
Total Suspended Solids	30
Settleable Solids	0.1
Total Coliform Bacteria (organisms per 100 ml)	1000
Nitrate Nitrogen as N	10.0
Total Nitrogen as N	10.0
Oils & Grease	15.0
Fluoride	2.4
Chlorine	1.0
Boron	20.0
MBAS (foaming agents)	1.0
pH (standard units)	6.5-8.5

The plant currently is capable of meeting nearly all the standards as shown earlier. However, the plant effluent is not being chlorinated so standards for chlorine residual (at least 1.0 mg/L) and total coliform (not more than 1000 per 100 ml) are not met. The plant was not designed to provide removal of nitrogen.

In addition to these numerical standards, the plant is allowed to discharge no more than 15 percent of the average monthly BOD and SS concentrations in the influent sewage. When influent wastewater concentrations exceed 100 mg/L, these standards can be achieved. In some months, however, influent concentrations are less than 80 mg/L due to high groundwater infiltration in the sewer system. Under these conditions, the criterion for 85-percent removal is difficult to achieve. The EPA has recently promulgated rules for trickling-filter plants that relax the percent-removal requirements; these regulations should be incorporated into the discharge permit.

Through discussions with State officials, it is understood that the groundwater at the boundary of the base is also subject to certain additional standards (as measured by sampling existing monitoring wells). These Class 1 standards are shown in Table 3-3 and are taken from Massachusetts Groundwater Quality Standards 314 CMR 6.00 effective October 1983.

TABLE 3-3

ADDITIONAL GROUNDWATER QUALITY STANDARDS
FOR CLASS I GROUNDWATERS

Primary Effluent Limitations

Parameter	Limit (mg/L except as noted)
Coliform Bacteria	Shall not be discharged in amounts sufficient to render groundwaters detrimental to public health, safety or welfare, or impair the groundwater for use as a source of potable water.
Arsenic	0.05
Barium	1.0
Cadmium	0.01
Chromium	0.05
Fluoride	2.4
Lead	0.05
Mercury	0.002
Total Trihalomethanes	0.1
Selenium	0.01
Silver	0.05
Endrin	0.0002
Lindane	0.004
Methoxychlor	0.1
Toxaphene	0.005
Chlorophenoxys	0.1
Silvex	0.1

TABLE 3-3
(continued)

Radioactivity	Shall not exceed the maximum radionuclide contaminant levels as stated in the National Interim Primary Drinking Water Standards.
Toxic pollutants (other than those listed above)	Shall not exceed "Health Advisories" which have been adopted by the Department and/or EPA. A toxic pollutant for which there is no available "Health Advisory" and for which there is not sufficient data available to the Department for the establishment of a "Health Advisory" will be prohibited from discharge.

Secondary Effluent Limitations

Parameter	
Copper	1.0
Iron	0.3
Manganese	0.05
Sulfate	250
Zinc	5.0
All other pollutants	None in such concentrations which in the opinion of the Director would impair the groundwater for use as a source of potable water or cause or

TABLE 3-3
(continued)

	contribute to a condition in contravention of standards for other classified waters of the Commonwealth.
<u>Additional Effluent Limitations</u>	
Chlorides	250
Total Dissolved Solids	1000

4.0 DESCRIPTION OF ALTERNATIVES

4.1 INTRODUCTION

Five alternatives were evaluated to enable the Otis ANG Base to meet its revised discharge permit. The alternatives evaluated were:

- Alternative 1 -- Pump raw wastewater to the Falmouth municipal WWTP for treatment and disposal.
- Alternative 1A -- Pump treated wastewater to the Falmouth municipal WWTP site for disposal in independent infiltration basins.
- Alternative 2 -- Utilize the existing wastewater treatment plant followed by land treatment.
- Alternative 3 - Construct a new biological nutrient removal treatment facility.
- Alternative 4 - Pump treated wastewater to a northern base site for disposal.

This chapter describes the five alternatives in detail.

4.2 ALTERNATIVE 1

Under Alternative 1, the existing treatment facility would be abandoned, and the Otis wastewater would be pumped to the Falmouth WWTP for treatment and disposal. The alternative consists of two components: (1) a conveyance system, and (2) a treatment and disposal system.

4.2.1 CONVEYANCE SYSTEM

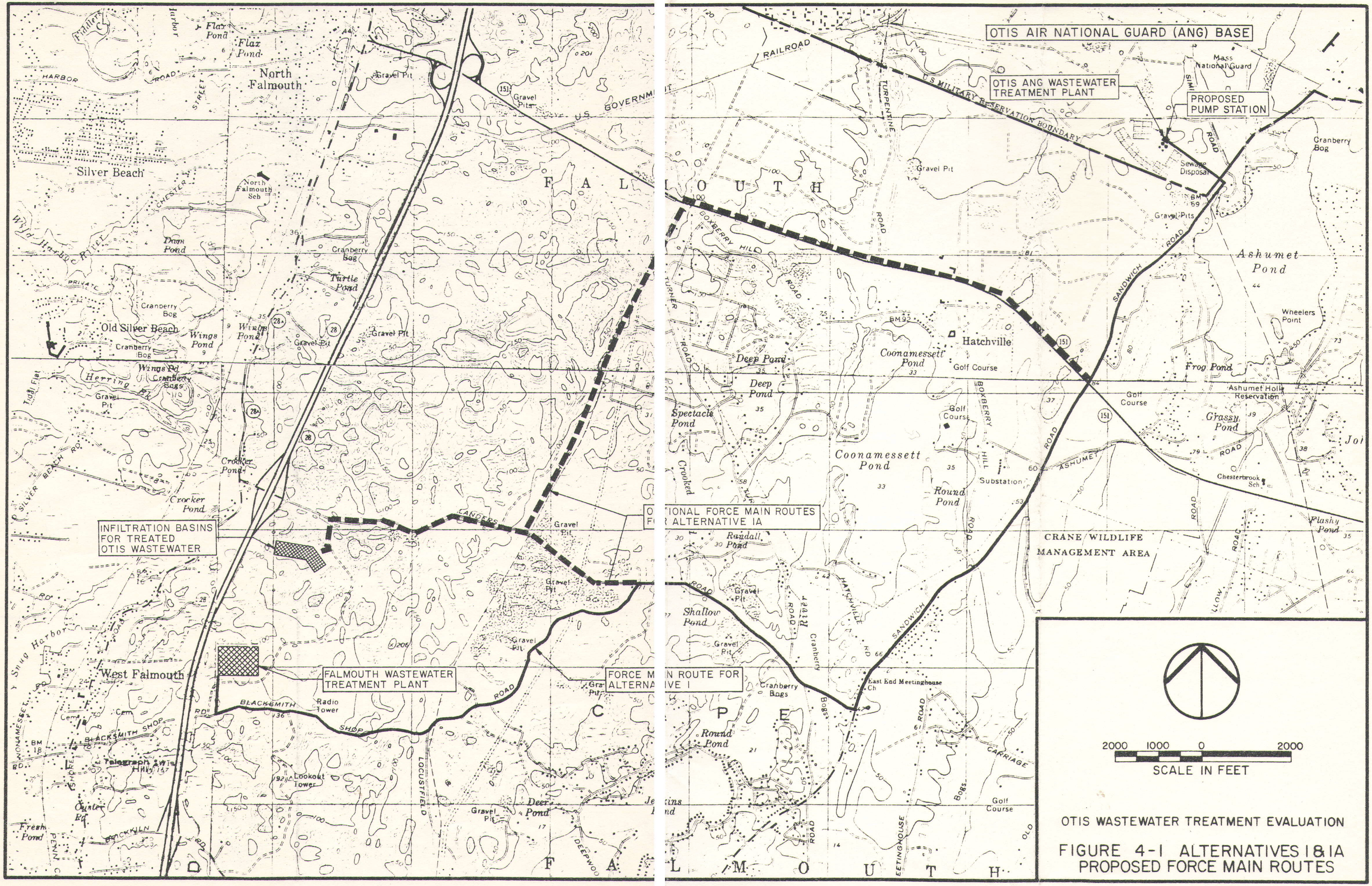
The conveyance system would consist of a prefabricated pump station, wet well and force main.

The pump station would be constructed near the headworks of the existing plant and be equipped with two centrifugal wastewater pumps each with a capacity of 1.0 mgd and 50 HP motors. Pumps of this size are required to maintain a minimum velocity of 2 ft/sec within the force main. Systems would be provided to control formation of hydrogen sulfide or release of obnoxious odors from the raw sewage pumping facilities. Provision would be made at the pump station for the addition of sodium hydroxide or sodium hypochlorite to control hydrogen sulfide formation in the wet well and force main. In addition, a carbon column would be provided for odor control for the treatment of the air venting from the wet well and pump station.

To ensure continuous operation of the pump station during power outages, the station would be automatically connected to the existing back-up generator at the treatment facility.

The wet well would be of 10-ft diameter, constructed of reinforced concrete. It would have an operating capacity of 3,500 gallons. Normally three starts per pump per hour would be required to pump design flows.

A 12-in diameter ductile iron force main would be constructed from the pump station to the headworks of the Falmouth WWTP, a total length of about 40,000 ft. As shown on Figure 4-1, the force main would be routed from the Otis plant cross-country to Sandwich Road. It would proceed southwesterly along Sandwich Road until Landers Road, from which point it would proceed in a northwesterly direction until Blacksmith Shop Road. The force main would follow Blacksmith Shop Road to the Falmouth WWTP. Given the length of this force main and resulting friction headloss of about 90 ft, the 40 ft higher elevation of the Falmouth WWTP, and miscellaneous piping headlosses, the total dynamic head on the Otis pumping station would be about 140 ft.



OTIS WASTEWATER TREATMENT EVALUATION

FIGURE 4-1 ALTERNATIVES I & IA PROPOSED FORCE MAIN ROUTES

4.2.2 TREATMENT AND DISPOSAL

Treatment and disposal of the Otis wastewater would occur at the Falmouth WWTP for Alternative 1. That plant, now under construction for 1986 start-up, consists of aerated ponds in series followed by infiltration basins. During the months of March through October, a portion of the Falmouth effluent will be applied by spray irrigation to woodlands.

The Falmouth WWTP will have an ultimate design-year summer flow of 1.29 mgd. At those conditions, the plant will consist of five aerated ponds, eight infiltration basins, and associated spray irrigation areas. For the purposes of this report, it was assumed that the Otis flow would require treatment capacity beyond the ultimate design capacity of the Falmouth WWTP and that the Otis flow would be handled by expanded aerated ponds and infiltration basins and not by the spray irrigation areas.

Table 4-1 presents the design criteria for expansion of the Falmouth WWTP. As shown in the table, the Otis average annual design flow would add about 23 percent to the Falmouth plant capacity. This design flow from Otis would require the construction of two additional aerated ponds, for a total of seven, and three additional infiltration basins, for a total of 11. The installed blower capacity for the aerated ponds has sufficient capacity to meet the requirements of the additional Otis flow. The two new aerated ponds, however, will require additional aeration piping.

Figure 4-2 shows a plan view of the Falmouth WWTP with the additional aerated ponds and infiltration basins also shown.

4.3 ALTERNATIVE 1A

Under Alternative 1A, the existing treatment facility would be fully operational. The treated effluent would be chlorinated and pumped to the Falmouth WWTP for disposal. The alternative consists of two components: (1) a conveyance system, and (2) an infiltration basin disposal system.

TABLE 4-1

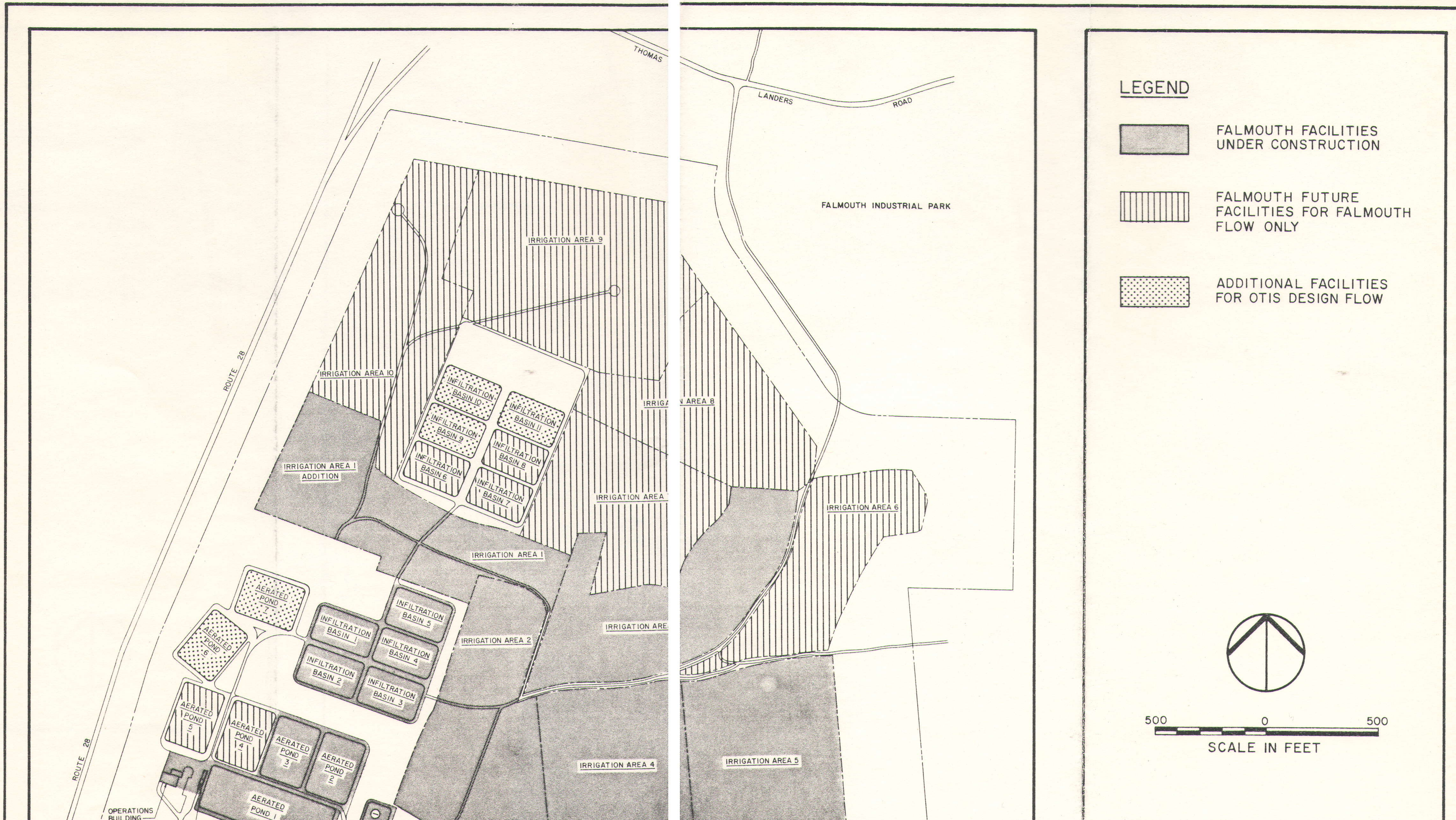
DESIGN CRITERIA FOR EXPANSION OF
FALMOUTH WWTP

	Design
Average Annual Otis Flow, mgd	0.3
Falmouth Design Year Summer Flow, mgd(1)	1.29
Total Flow, mgd	1.59
Falmouth Aerated Ponds Volume, mg	20.4
Additional Volume Required for Otis, mg	6.4
Total Aerated Pond Volume, mg	26.8
Falmouth Aerated Ponds, No.(2)	5
Additional Ponds Required for Otis, No.	2
Total Ponds, No.	7
Installed Aeration Capacity, scfm	4,500
Falmouth Aeration Requirements, scfm	4,000
Additional Aeration Required for Otis, scfm	300
Total Aeration Requirements, scfm	4,300
Infiltration Basin Area, sq ft (each)	37,500
Falmouth Infiltration Basins, No.(3)	8
Additional Basins for Otis, No.	3
Total Infiltration Basins, No.	11

(1) Based on future sewering needs.

(2) Ponds vary in capacity due to site limitations.

(3) Only a portion of Falmouth effluent flows to infiltration basins. The remainder is irrigated.



OTIS WASTEWATER TREATMENT EVALUATION

FIGURE 4-2 ALTERNATIVE I- PLAN OF FALMOUTH WASTEWATER TREATMENT PLANT WITH EXPANSION FOR OTIS FLOWS

4.3.1 CONVEYANCE SYSTEM

The conveyance system would consist of a prefabricated pump station, wet well and force main.

The pump station and wet well would be as described in Section 4.2.1. The effluent would be chlorinated before it reaches the wet well. Not only would the chlorine disinfect the effluent but it would also help eliminate any odors present. With a maximum daily flow of 0.5 mgd, the contact time for the chlorine in the force main would approach ten hours, well above the accepted standard of 15-30 minutes for disinfection.

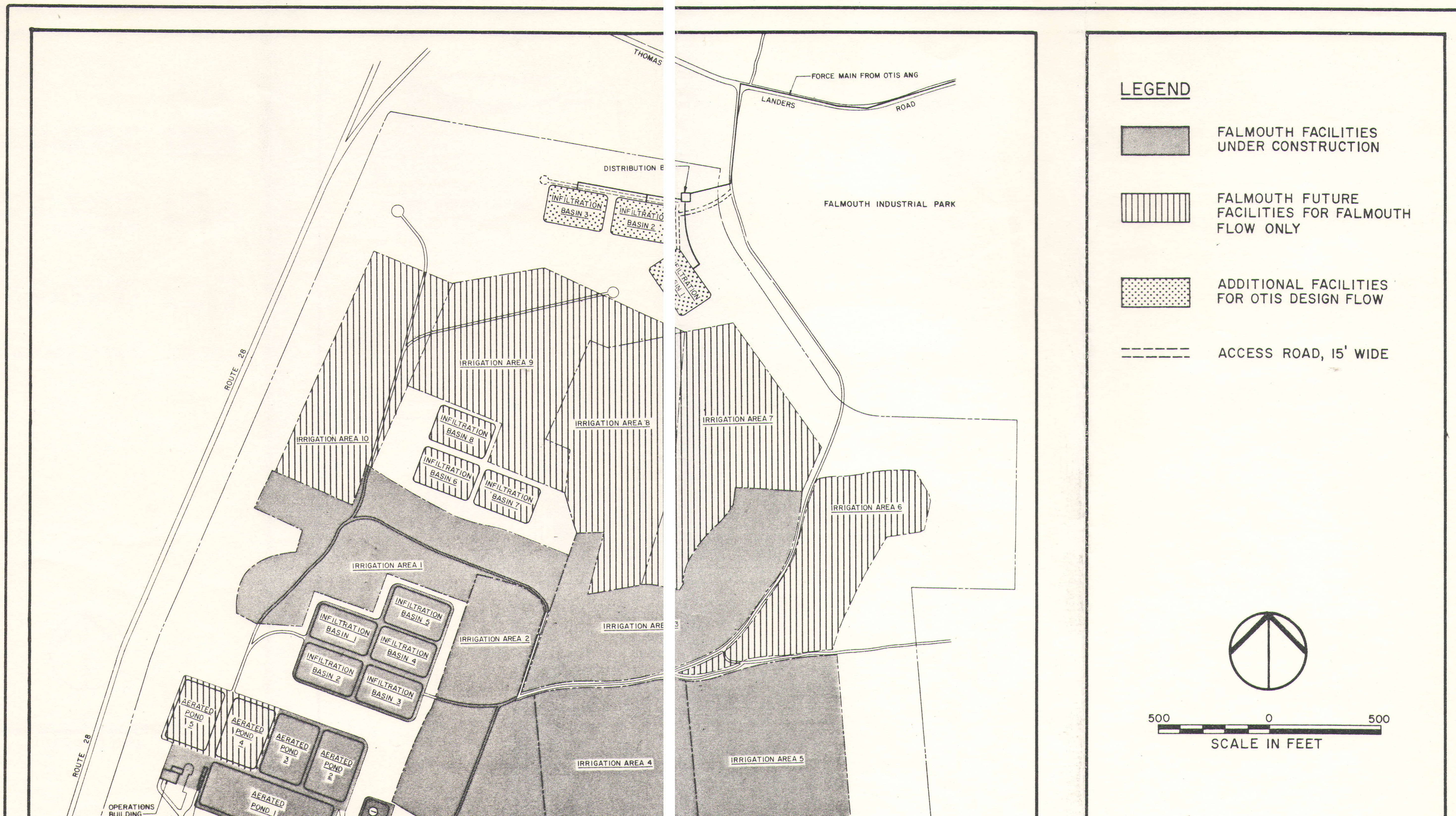
A 12-in-diameter ductile iron force main would be constructed from the pump station to three new infiltration basins located on the northern border of Falmouth WWTP property. As shown on Figure 4-1, there are two alternative routes for the force main.

Both routes would be constructed cross-country to Sandwich Road and then southerly to Route 151. In one alternative, the force main would head southerly to Landers Road, where it would turn and head westerly to the Falmouth site for disposal. The total length of force main under this alignment would be about 32,000 ft.

In another alternative, the force main would proceed along Route 151 to Sam Turner Road. Heading south on Sam Turner Road, the force main would follow a telephone easement to Landers Road. It would then head west to the Falmouth site and final disposal in the infiltration basins. The total length of this alignment would be about 32,500 ft.

4.3.2 INFILTRATION BASINS

Otis' effluent would be discharged to three new infiltration basins constructed at the Falmouth WWTP site -- independent of Falmouth operations as shown on Figure 4-3. The exact location of these basins



OTIS WASTEWATER TREATMENT EVALUATION

FIGURE 4-3 ALTERNATIVE IA-
PLAN OF FALMOUTH SITE
SHOWING INFILTRATION BASINS
FOR OTIS FLOWS

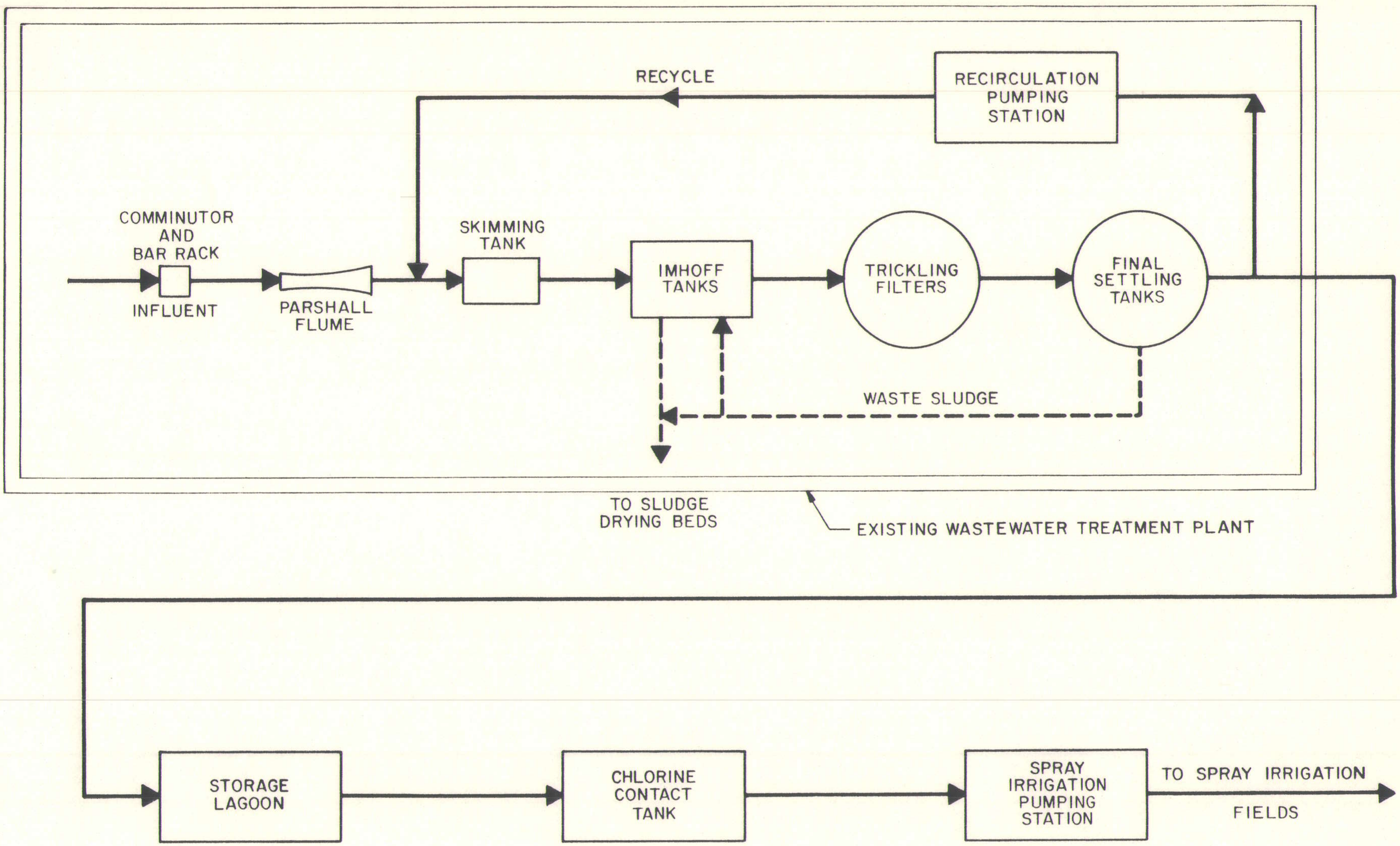
will have to be determined after soil borings and determination of the boundaries of a wetland area by town of Falmouth officials. If the wetland area precludes the location of basins as shown on Figure 4-3, the beds could be located as shown for Alternative 1. These beds each would be 37,500 sq. ft. in area, and 5-ft deep with a side slope of 2:1. The beds would be loaded at a hydraulic loading rate of 3 gpd/ft^2. Flow would be by gravity, controlled by manual valves for alternating bed service.

4.4 ALTERNATIVE 2

Under Alternative 2, the existing wastewater treatment plant would continue to be operated. Effluent from the secondary clarifier would flow to storage lagoons, however, instead of to the sand filter beds. During the eight warmer months of the year, the effluent would be pumped from the storage lagoons, passed through a chlorine contact chamber and then to spray irrigation areas to be constructed in the woodlands around the Otis treatment plant. Nitrogen present in the wastewater effluent would be reduced to less than 10 mg/l in the groundwater by uptake in vegetation and by process of naturally occurring nitrification, denitrification and storage in the soil. Figure 4-4 shows a schematic of the process flow. The following section describes the components of this alternative.

4.4.1 COMPONENTS OF LAND TREATMENT

Table 4-2 presents a summary of the design criteria for land treatment. The first new component to be constructed would be a storage lagoon, 15 ft deep with a sidewater depth of 12 ft, sized to provide four months of storage at average flow. To prevent any infiltration of the wastewater into the soil, the entire lagoon would be lined with soil cement or a synthetic liner. For the average design flow of 0.3 mgd, nearly 36 million gallons of storage would be required. This volume would be provided by one or more lagoons encompassing an area of approximately 11.1 acres.



OTIS WASTEWATER TREATMENT EVALUATION

FIGURE 4-4 PROCESS FLOW DIAGRAM FOR ALTERNATIVE 2
EXISTING WASTEWATER TREATMENT FOLLOWED BY
LAND TREATMENT FACILITY

Table 4-2

DESIGN CRITERIA FOR
LAND TREATMENT

	Design
Average Annual Flow, mgd	0.3
Months of Operation	8
Months of Storage	4
Storage Volume Required, mg	36
Average Water Depth, ft	12
Freeboard, ft	3
Total Area including Dikes, ac	11.1
Actual Irrigation Rate, mgd	0.45
Schedule, no. of days/wk	5
No. hours/day	24
Daily Irrigation Rate (gpm)	440
No. of Centrifugal Pumps	2
Hydraulic Loading Rate, in/ac/wk	2
Area Required, ac	60
No. of Irrigation Areas	5
Total no. of Nozzles	230
Nozzle Flow Rate, gpm	9.8
Minimum Nozzle Pressure, psi	30
Length of Force Mains, ft	2,600
Length of Irrigation Pipe, ft	32,000

The effluent from the storage lagoons would flow through a chlorine contact chamber to provide 15 minutes of detention time at peak pumping rate. The contact chamber of 11,000 gallons would be constructed between the storage lagoons and the pump station.

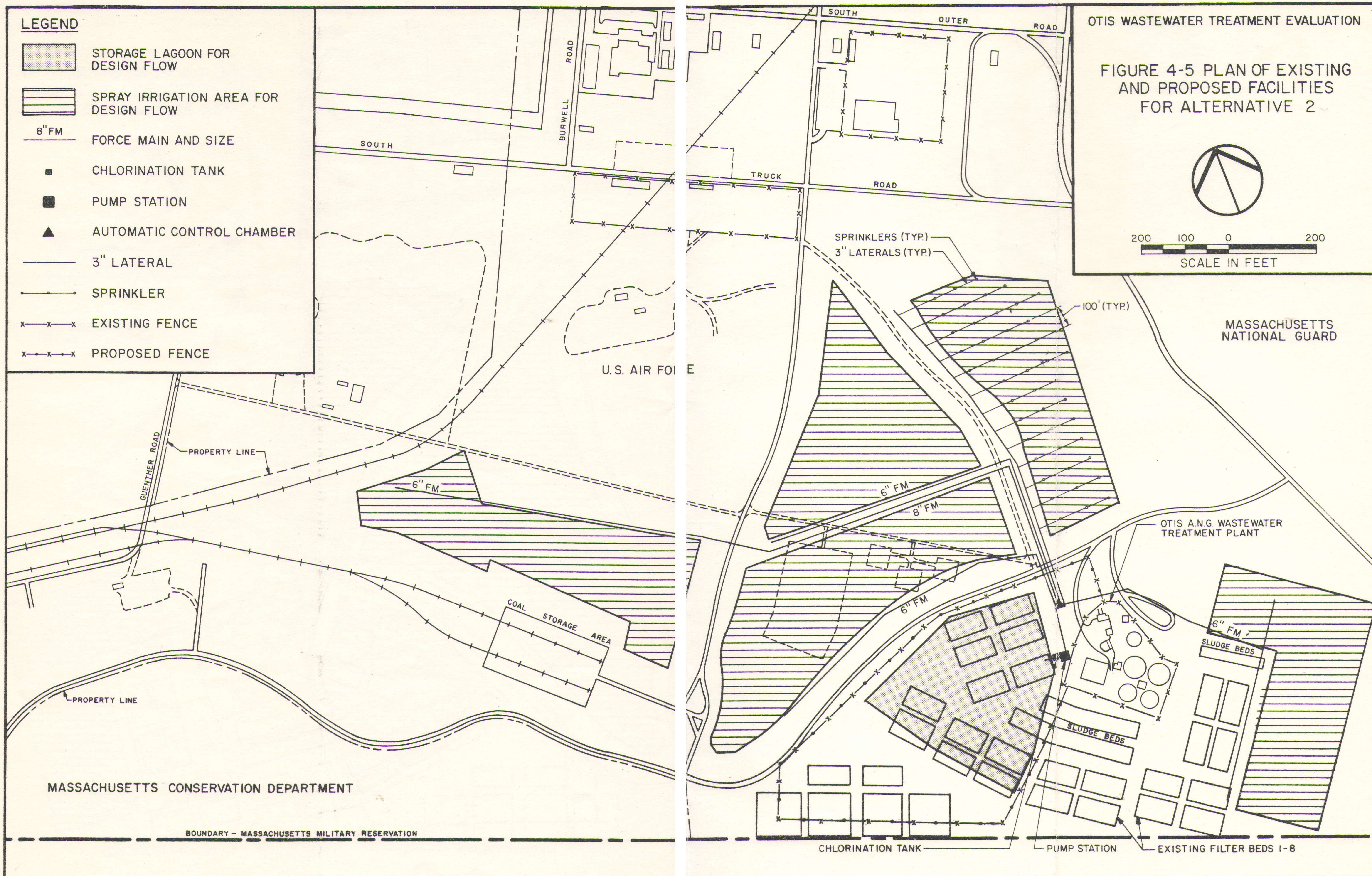
The land treatment system would be designed for 24 hrs/day operation for five days per week, resulting in an irrigation rate of 440 gpm.

The pump station would be constructed in a below-grade concrete chamber with a brick and block superstructure. The station would be equipped with two end-suction centrifugal pumps, each with a capacity of 440 gpm and 40 HP motors, and would be connected to the existing standby generator at the treatment facility.

The irrigation areas were sized for a loading rate of 2 in/ac/wk, the same rate as at the Falmouth wastewater treatment plant. Sixty acres of irrigation area would be required for the design flow. The individual irrigation fields would each be approximately 12 acres in area. Each area would have 3-in diameter aluminum pipe (laterals) laid on-grade at a spacing of 100-ft apart. On each lateral, a sprinkler mechanism would be placed every 100-ft, giving a grid work of sprinklers spaced 100-ft on center. Some 230 sprinkler nozzles would be required. The laterals would be connected to a 6- or 8-in diameter force main leading from the pump station.

As designed, the system would allow the application of wastewater to one field at a time and would be controlled by manually operated valves at the pumping station.

Figure 4-5 shows a site layout for the land treatment alternative. As can be seen from the figure, the five spray irrigation areas surround the existing plant.


OTIS WASTEWATER TREATMENT EVALUATION
FIGURE 4-5 PLAN OF EXISTING AND PROPOSED FACILITIES FOR ALTERNATIVE 2
LEGEND
STORAGE LAGOON FOR DESIGN FLOW
SPRAY IRRIGATION AREA FOR DESIGN FLOW
8" FM
FORCE MAIN AND SIZE
CHLORINATION TANK
PUMP STATION
AUTOMATIC CONTROL CHAMBER
3" LATERAL
SPRINKLER
EXISTING FENCE
PROPOSED FENCE
200 100 0 200
SCALE IN FEET
SOUTH OUTER ROAD
SOUTH TRUCK ROAD
BURWELL ROAD
GUENTHER ROAD
U.S. AIR FORCE
MASSACHUSETTS NATIONAL GUARD
SPRINKLERS (TYP.)
3" LATERALS (TYP.)
100' (TYP.)
6" FM
8" FM
PROPERTY LINE
COAL STORAGE AREA
OTIS A.N.G. WASTEWATER TREATMENT PLANT
SLUDGE BEDS
MASSACHUSETTS CONSERVATION DEPARTMENT
BOUNDARY - MASSACHUSETTS MILITARY RESERVATION
CHLORINATION TANK
PUMP STATION
EXISTING FILTER BEDS 1-8

4.5 ALTERNATIVE 3

Under this alternative, a new wastewater treatment plant would be constructed at Otis providing biological treatment for removal of nitrogen. Because this process is new, this section discusses the rationale for selection of this particular method of nitrogen removal and presents a description of the facilities and their siting.

4.5.1 SELECTION OF THE BARDENPHO PROCESS

As noted earlier in this report, the existing plant is not designed for, and is not, removing nitrogen. Effluent now averages about 20 mg/L total nitrogen. Under the new permit, a maximum nitrate-nitrogen concentration of 10 mg/L and a maximum total nitrogen concentration of 10 mg/L is allowed.

There are many methods of controlling nitrogen levels in wastewater. The most widespread method, nitrification, oxidizes organic and ammonia-nitrogen to nitrate-nitrogen, a less objectionable form for most discharges. This method would not satisfy the Otis standard, however, as nitrate-nitrogen concentrations would exceed 10 mg/L. Wastewater treatment plants providing complete removal of nitrogen represent only a very small percent of the total number of advanced wastewater treatment plants nationwide. Some of the methods employed at these plants include denitrification, ion exchange, ammonia stripping, breakpoint chlorination, and the land treatment method that is described under Alternative 2.

Ion exchange, ammonia stripping and breakpoint chlorination are energy-intensive processes, and, as such, they have been used only on a limited basis. Conventional denitrification with methanol addition as a carbon source for denitrifying bacteria has been used more often, but it bears high operating costs. In the early 1970s, a new process was developed using organic material in the raw wastewater as the carbon source, thus avoiding the purchase of chemicals. This process is known

as the Bardenpho process and Camp Dresser & McKee Inc. has designed several wastewater treatment plants using this method. Full-scale facilities have now been operated for six years in the U.S., showing excellent nitrogen removal results. For these reasons, this process was selected for comparison with the other alternatives of this report.

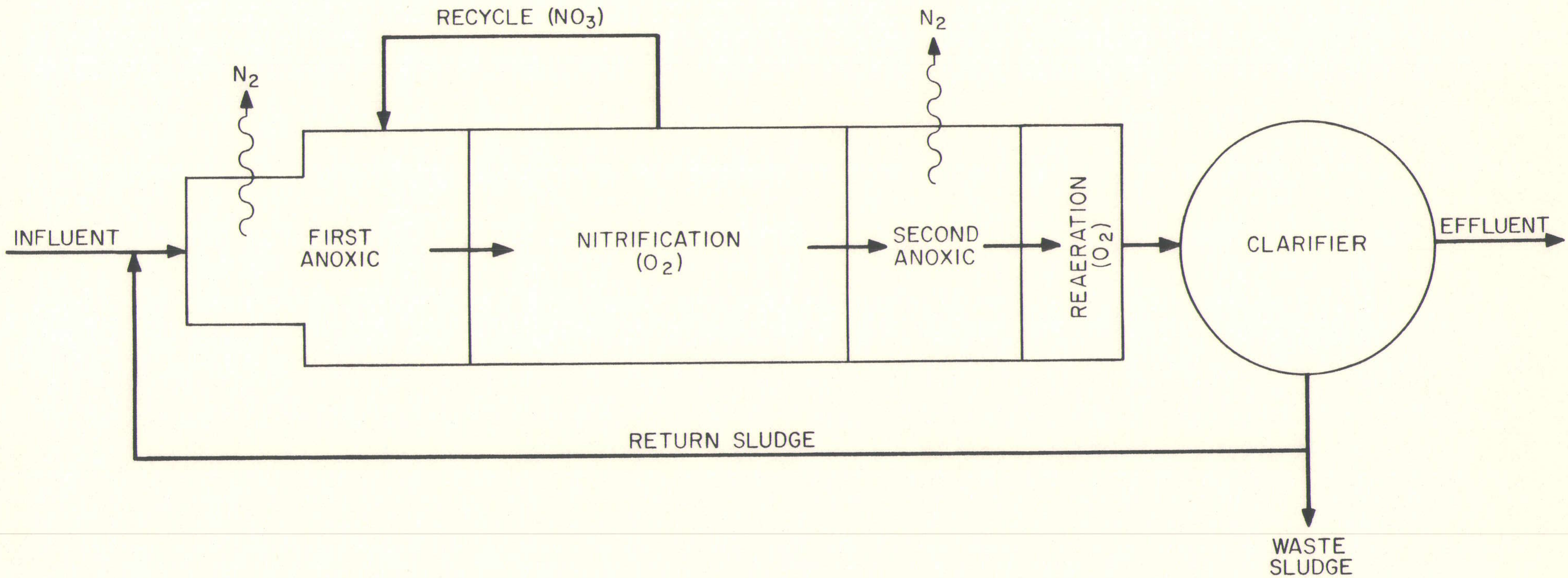
4.5.2 DESCRIPTION OF THE BARDENPHO PROCESS

The Bardenpho process shown schematically in Figure 4-6 is a four-stage, complete-mix activated-sludge process, with alternating stages of anoxic and aerobic conditions. Anoxic stages have very low levels of dissolved oxygen (usually near zero), with nitrate-nitrogen present. Aerobic stages maintain a dissolved oxygen concentration near 2 mg/L by the use of mechanical aerators or by diffused aeration.

The most important stage for nitrogen removal is the first anoxic stage. Here, a large portion of the fully nitrified mixed liquor from the second (nitrification) stage is recycled back and mixed with raw wastewater and return activated sludge from the final clarifiers. In the absence of the free oxygen, bacteria use BOD in the raw wastewater and reduce the nitrates present in the recycle to gaseous nitrogen. About two-thirds of the total nitrogen removed in Bardenpho process is released as a gas in this stage.

In the second (nitrification) stage, oxygen is introduced to oxidize BOD and ammonia. BOD is converted to new cell mass and carbon dioxide. Ammonia-nitrogen is converted to nitrate-nitrogen. To allow nitrifying bacteria to dominate this stage, a much longer hydraulic retention time is needed compared to other stages.

In the second anoxic stage, nitrate not recycled to the first stage is reduced in the absence of free oxygen to nitrogen gas. The remaining nitrogen is removed here. The last stage (reaeration) is accomplished in a relatively short detention time. Here the dissolved oxygen is increased to 3 to 4 mg/L before the wastewater is introduced to the final clarifier. This prevents anaerobic conditions in the effluent and return sludge streams.



OTIS WASTEWATER TREATMENT EVALUATION

FIGURE 4-6 PROCESS FLOW DIAGRAM FOR BIOLOGICAL NUTRIENT REMOVAL (BARDENPHO PROCESS)

Table 4-3 shows the design criteria for biological nitrogen removal for the Otis WWTP. The plant would be designed to handle the maximum daily flow of 0.5 mgd. A total of about 18 hours of hydraulic detention time is required to accommodate the four-stage process. Two 30-ft diameter secondary clarifiers would be required. The treated wastewater would flow to a new chlorine contact tank and then to the existing sand filter beds.

Waste activated sludge is well stabilized during the process because of the long solids residence time in thesystem. The sludge would be pumped to the existing Imhoff tank, which would act as a sludge storage tank. Periodically, sludge would be applied to the sludge drying bed. Dried sludge would be landfilled at the Base landfill. Although records are not available showing present sludge production, it is likely that the sludge generated annually with the Bardenpho process is about equal to the present quantities.

4.5.3 FACILITY SITING

In the layout of the Bardenpho treatment facilities, consideration was given to maximizing the use of existing facilities as well as to maintaining existing treatment operations during construction. Existing facilities that would become part of the new facilities are the headworks, including flow measuring and comminutor; the administration building which houses the laboratory; the sludge transfer station, which would be retrofitted with the return and waste activated sludge pumps; the Imhoff tanks which would be converted to sludge storage; the secondary clarifiers which would be converted to aeration basins for the Bardenpho treatment process; and the sand filter beds.

Figure 4-7 shows the proposed plant layout. The main portion of the plant would be located to the south of the existing trickling filters. This arrangement is influenced by the elevation of the influent sewer and the elevation of the effluent discharge line to the sand filter beds.

TABLE 4-3

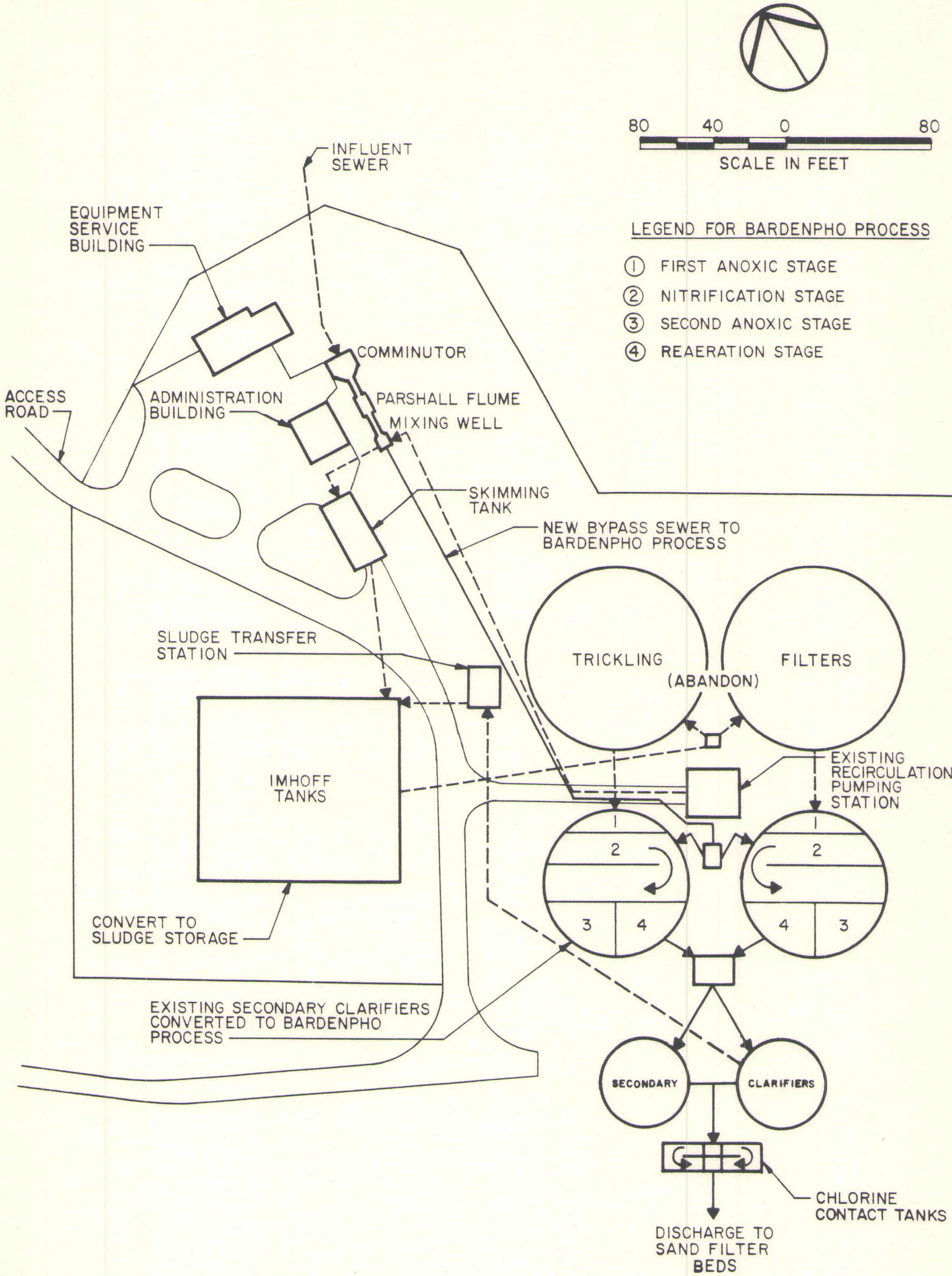
DESIGN CRITERIA FOR

BIOLOGICAL NUTRIENT REMOVAL

	Design
Average Daily Flow, mgd	0.3
Maximum Daily Flow, mgd	0.5
First Anoxic Zone	
Detention time, hrs	3.0
Volume, gal	62,500
Nitrification Zone	
Detention time, hrs	11.1
Volume, gal	231,000
Second Anoxic Zone	
Detention time, hrs	3.0
Volume, gal	62,500
Reaeration Zone	
Detention time, hrs	0.5
Volume, gal	10,400
Total Reactor	
Detention time, hrs	17.6
Volume, gal	366,400
Secondary Clarifiers	
Number	2
Diameter, ft	30
Surface area, sq ft	1,414
Loading rate, lb/sq ft-day	18
Loading rate, gpd/sq ft	350

TABLE 4-3
(continued)

	Design
Chlorine Contact Tanks	
Peak flow, gpm	560
Detention time, min	15
Volume required, cu.ft.	1,110
Volume supplied, cu.ft.	2,500
Sludge Management	
Waste sludge, lb/d	312
Waste sludge, gal/wk	26,000
Imhoff tank storage capacity, gal	1,040,000
Detention time, wks	40
Sludge drying beds, no.	1
Area each, sq.ft.	4,800
Cake to disposal, cu yd/wk	2.7



OTIS WASTEWATER TREATMENT EVALUATION

FIGURE 4-7 SITE PLAN FOR BIOLOGICAL NUTRIENT REMOVAL

In accordance with State regulations, two process trains would be required so that the entire treatment plant is not out of service for an equipment repair. Each train would be capable of accepting up to a maximum of 0.25 mgd of wastewater. Each train would include a four-stage activated sludge reactor, a 30-ft diameter secondary clarifier and a chlorine contact tank. The first and third stage of the process would be equipped with mixers. The second and fourth stage would be equipped with mechanical surface aerators or diffused aeration system. Mixed liquor recirculation pumps would be housed in the existing recirculation pumping station. Sludge pumps would be housed in the existing sludge transfer station.

4.6 ALTERNATIVE 4

Under Alternative 4, the existing wastewater treatment facility would be fully operational. The treated effluent would be chlorinated and pumped to new sand filter beds located at the northern end of the base. The reason for examining this alternative is to minimize the volume of groundwater impacted from the discharge. Compared to all other alternatives, the area of degraded groundwater would be significantly less and since the discharge is near the Cape Cod Canal additional dilution is available. The alternative consists of two components: (1) a conveyance system, and (2) an infiltration basin disposal system.

4.6.1 CONVEYANCE SYSTEM

The conveyance system would consist of a prefabricated pumping station, wet well and force main. The pumping station would be similar to that described for Alternative 1A.

A 12-in-diameter ductile iron force main would be constructed from the pump station to the disposal site. As shown on Figure 4-8, the force main would be routed through the portion of the base to a powerline right-of-way proceeding northerly along the western edge of the base to the disposal site. The total length of the force main would be about 50,000 ft.

OTIS WASTEWATER TREATMENT EVALUATION

FIGURE 4-8 ALTERNATIVE 4
PROPOSED FORCE MAIN ROUTE

4.6.2 INFILTRATION BASINS

The infiltration basins would be located about 300 ft from the easterly roadway that borders the Cape Cod Canal. This location was selected because all the land falling within the zone of degraded groundwater is government owned. The basins would occupy about 90,000 square feet and would be similar to those described for Alternative 1A.

5.0 COSTS OF ALTERNATIVES

5.1 GENERAL

This chapter presents the capital and operating and maintenance costs for the alternatives described in Chapter 4. The following sections describe the basis of the cost estimates.

5.1.1 CAPITAL COSTS

Cost estimates are based upon a September 1985 projected Engineering News-Record (ENR) Construction Cost Index of 4300. A capital cost was prepared for the average annual flow of 0.3 mgd. Thirty percent of total project costs are for engineering and contingencies.

5.1.2 UNIT OPERATING AND MAINTENANCE COST

All unit operating costs are based on current costs.

- Electricity -- A cost of $0.075/kW-hr was used for electricity cost for facilities sited at Otis. For facilities sited at the Falmouth WWTP, a cost of $0.09/kW-hr was used, based upon the anticipated Falmouth WWTP rate structure.

- Fuel oil -- The unit value of fuel oil was based upon the current cost at Otis of $0.95/gal for facilities sited at Otis. A unit value of $1.25/gal was used for facilities sited at Falmouth WWTP, based upon the current costs to the Town of Falmouth.

- Sodium hypochlorite -- A cost of $0.50/gal was used for odor control facilities sited at Otis and Falmouth, based on quotes from local suppliers.

- Sodium hydroxide -- A unit cost of $0.40/gal was used, based on quotes from local suppliers.

- Chlorine -- A unit cost of $0.50/lb was used for the cost of chlorine, based on quotes from local suppliers.

- Operators wages -- Based on an average of wages paid to Otis wastewater treatment plant personnel, the yearly labor rate used was $31,200/yr. This value includes a 30-percent allowance for fringe benefits. The same average annual cost was also used for the Falmouth operators. The cost of the existing operator for the Otis collection system was not included for any of the alternatives, as this cost would be constant for all alternatives.

- Maintenance and repair -- The maintenance cost for all alternatives is based on 1 percent of the capital improvement cost and a periodic replacement cost at 2 percent of the equipment cost.

5.2 COSTS OF ALTERNATIVE 1

Table 5-1 presents a summary of the capital costs for the Alternative 1 facilities described in Chapter 4.0 (pumping of Otis raw wastewater to the Falmouth plant for treatment and disposal). The operating and maintenance costs for Alternative 1 are presented in Table 5-2. Since this alternative involves construction of facilities at both the Otis and Falmouth WWTP sites, the summary tables provide the costs associated with each site.

The operating and maintenance costs at Otis are based upon predicted pump operating time and utility and chemical usage. The labor costs are

TABLE 5-1

CAPITAL COST
ALTERNATIVE 1

Description	Cost
Improvements @ Otis WWTP	
Pump Station	$ 320,000
Force Main	1,680,000
Improvements @ Falmouth WWTP	
Aerated Ponds	$ 1,060,000
Infiltration Basins	140,000
Yard Piping	270,000
Yard Structures	195,000
Engineering & Contingencies	1,100,000
TOTAL	$ 4,765,000

TABLE 5-2

OPERATING AND MAINTENANCE COST
ALTERNATIVE 1

Description	Cost
Facilities @ Otis	
Labor	$ 30,000
Fuel	2,000
Electricity	6,000
Chemicals	6,000
Facilities @ Falmouth WWTP	
Labor	$ 36,000
Fuel	2,000
Electricity	21,000
Chemicals	2,000
Maintenance & Repair	$ 51,000
TOTAL	$ 156,000

based upon one operator at a 40-hour work week. The operating and maintenance costs associated with the Falmouth WWTP are based upon the Town of Falmouth 1986 projected operating budget. The total projected operating cost to run the Falmouth WWTP can be divided by the total gallons of wastewater treated to obtain a unit cost per gallon. Otis would be charged at this unit cost times the gallons of wastewater that Otis discharges to Falmouth. For this reason, the costs shown in Table 5-2 are those associated with Otis flow only and are assumed to be proportional to the total flow of Falmouth. The Otis design flow is 23 percent of the Falmouth design flow. The assumption was made that Falmouth would not add any operating cost surcharge for use of the expanded treatment facilities.

5.3 COSTS OF ALTERNATIVE 1A

Table 5-3 presents the capital costs of Alternative 1A - treatment of wastewater at Otis facilities and pumping of effluent to Falmouth for disposal. Under this alternative, a separate set of infiltration basins would be constructed at the Falmouth plant site. Costs for these basins would be greater than for those included in Alternative 1, as a separate access road and significant earthmoving are required.

Table 5-4 presents the operating and maintenance costs for Alternative 1A. Costs for operation of the Otis plant are based on existing costs. The major cost item is labor, which is based on a total of six operators including superintendent. Current staffing is based on a 7-day/week, 24-hr/day schedule. (It may be possible to reduce coverage to 5- or 6-days/week and one shift per day, with provision of alarms for emergencies when the plant is not manned. To be conservative, however, we have based costs on current staff.) As shown in the table no charges for use of the Falmouth WWTP are shown. This assumption cannot be verified until after discussions are held with Falmouth officials.

TABLE 5-3

CAPITAL COST

ALTERNATIVE 1A

Description	Cost
Improvements @ Otis WWTP	
Pump Station	$ 320,000
Force Main	1,320,000
Effluent Disposal Facilities	
Infiltration Basins	405,000
Yard Structures & Piping	185,000
Monitoring Wells	20,000
Engineering & Contingencies	675,000
TOTAL	$ 2,925,000

TABLE 5-4

OPERATING AND MAINTENANCE COST

ALTERNATIVE 1A

Description	Cost
Labor	$ 189,000
Fuel	4,000
Electricity	27,000
Chemicals & Supplies	9,000
Groundwater Quality Analysis	11,000
Maintenance & Repair	25,000
Falmouth Treatment Charges	0
TOTAL	$ 265,000

5.4 COSTS OF ALTERNATIVE 2

Chapter 4.0 presents a description of the items which are included in the construction costs. Table 5-5 presents a summary of the capital cost for Alternative 2 and Table 5-6 presents a summary of the operating and maintenance costs associated with Alternative 2.

The operating and maintenance costs include the current costs to operate the existing WWTP. For labor costs this includes one superintendent and five operators. An allowance is also made for analysis of groundwater for the land treatment system and a maintenance and repair budget sufficient to cover periodic replacement of equipment.

5.5 COSTS OF ALTERNATIVE 3

Table 5-7 presents the capital costs of Alternative 3 -- treatment by biological nutrient removal at Otis. Several cost items are for the rehabilitation and conversion of existing structures for the biological nutrient removal facilities. Bardenpho equipment costs include a one-time royalty fee to the equipment manufacturer. A contingency of $100,000 was included to take into account the longer construction period due to the requirement of phased construction.

Table 5-8 presents a summary of operation and maintenance costs for this alternative. For advanced wastewater treatment facilities of this type, a licensed operator, Grade 6 or 7, will be required. We have added the cost of a Grade 7 operator to the existing labor costs to represent the total annual labor costs.

5.6 COSTS OF ALTERNATIVE 4

Table 5-9 presents the capital costs of Alternative 4 -- pumping treated wastewater to a northern base site for disposal. Costs are similar to those for Alternative 1A except for a longer force main and less site work required for the infiltration basins. Table 5-10 presents the operation and maintenance costs for Alternative 4.

TABLE 5-5

CAPITAL COST

ALTERNATIVE 2

Description	Cost
Storage Lagoons	$ 1,290,000
Pump Station	410,000
Spray Irrigation	320,000
Yard Structures	200,000
Monitoring Wells	20,000
Instrumentation & Electrical	180,000
Tractor w/attachments	25,000
Engineering & Contingencies	735,000
TOTAL	$3,180,000

TABLE 5-6

OPERATING AND MAINTENANCE COST

ALTERNATIVE 2

Description	Cost
Labor	$ 189,000
Fuel	4,000
Electricity	30,000
Chemicals and Supplies	13,000
Groundwater Quality Analysis	11,000
Maintenance and Repair	25,000
TOTAL	$ 272,000

TABLE 5-7

CAPITAL COST

ALTERNATIVE 3

Description	Cost
Bardenpho Process Equipment	$ 295,000
Conversion of Clarifiers to Aeration Tanks	130,000
Recirculation Pumping	150,000
Sludge Pumping	100,000
Secondary Settling Tanks	290,000
Chlorine Contact Tanks	60,000
Sludge Drying Beds	30,000
Contingency for Phased Construction	100,000
Site Work	140,000
Yard Piping	110,000
Electrical	150,000
Instrumentation	80,000
Engineering & Contingencies	490,000
TOTAL	$2,125,000

TABLE 5-8

OPERATING AND MAINTENANCE COST

ALTERNATIVE 3

Description	Cost
Labor	$ 225,000
Electricity	25,000
Chemicals	10,000
Groundwater Quality Analysis	5,000
Maintenance and Repair	50,000
TOTAL	$ 320,000

TABLE 5-9

CAPITAL COST

ALTERNATIVE 4

Description	Cost
Improvements @ Otis WWTP	
Pump Station	$ 320,000
Force Main	2,050,000
Effluent Disposal Facilities	
Infiltration Basins	140,000
Yard Structures & Piping	185,000
Monitoring Wells	20,000
Engineering & Contingencies	815,000
TOTAL	$ 3,530,000

TABLE 5-10

OPERATING AND MAINTENANCE COST

ALTERNATIVE 4

Description	Cost
Labor	$ 189,000
Fuel	4,000
Electricity	27,000
Chemicals & Supplies	9,000
Groundwater Quality Analysis	11,000
Maintenance & Repair	25,000
TOTAL	$ 265,000

6.0 EVALUATION OF ALTERNATIVES

6.1 COST EFFECTIVENESS ANALYSIS

Cost estimates for the cost-effectiveness analysis are based on September 1985 costs (ENR Construction Cost Index of 4300), with no allowances provided for inflation of prices or wages over the planning period. A discount rate of 8-3/8 percent per year and a total life cycle of 20 years have been used. Wherever applicable, straight line depreciation has been assumed.

The cost-effectiveness analysis assumes that the plant is constructed to its design flow capacity and that flows remain constant throughout the planning period.

Life cycle cost factors were prepared to assist in calculating the present worth of capital costs. The cost factors take into account the initial capital cost, the present worth of salvage at the end of 20 years, and the present worth of any capital costs to replace equipment that will not last the full 20 years. Present-worth values were obtained by multiplying capital costs times the life cycle cost factor. The projected life for items evaluated in this study and the life cycle costs follow:

Item	Projected Life (years)	Life Cycle Cost Factor (Present Worth)
Mechanical Equipment	15	1.166
Structures	50	0.88

Uniform annual costs over the 20-year planning period were converted to present worth by multiplying by 9.55.

Table 6-1 presents a summary of the present worth analysis.

TABLE 6-1

PRESENT WORTH ANALYSIS

	Alternative 1	Alternative 1A	Alternative 2	Alternative 3	Alternative 4
Description	Pump to Falmouth for Treatment and Disposal	Pump Treated Wastewater to Falmouth for Disposal	Land Treatment	Biological Nutrient Removal	Pump Treated Wastewater to Northern Base Site for Disposal
Capital Costs	$ 4,765,000	$ 2,925,000	$ 3,180,000	$ 2,125,000	$ 3,530,000
Operating and Maintenance Costs	156,000	265,000	272,000	320,000	265,000
Total Present Worth	5,800,000	5,200,000	5,500,000	5,200,000	5,800,000
% Greater than Least Costly	12	-	6	-	12

6.2 COMPARISON OF ALTERNATIVES

In this section, we compare the five alternatives described in Chapter 4 on non-economic factors as well as costs. Table 6-2 is a summary of these factors.

6.2.1 COST

As shown in the previous section, Alternatives 1A and 3 have the lowest total present-worth cost compared to the other alternatives. Alternative 1A -- treatment at Otis and pumping to Falmouth for disposal -- has initial costs of about $800,000 greater than Alternative 3, but would save about $55,000 per year in operating costs. Alternative 2 is about 6-percent more costly than Alternatives 1A or 3, Alternatives 1 and 4 are both about 12 percent more costly than those Alternatives. The cost differences among these alternatives are not significant, given the degree of certainty attached to these cost estimates.

The present-worth analysis does not take into account inflation. If inflation is included in the cost analysis, alternatives with lower operation and maintenance costs become more attractive, tending to reduce still further the difference among these alternatives.

For the planning phase of a project cost, estimates have a typical accuracy of 10-15 percent. Therefore, on a percent worth basis, the four alternatives studied are considered to have equivalent costs and other factors should be used in selection of an alternative.

6.2.2 GROUNDWATER QUALITY IMPROVEMENTS

A comparison of projected effluent concentrations for the five alternatives to the State discharge permit and the existing plant is presented in Table 6-3. As shown, the existing wastewater treatment plant exceeds the standards for total coliform bacteria and total nitrogen. All of the five alternatives would be designed to meet the groundwater standards, but inasmuch as the alternatives are

TABLE 6-2

COMPARISON OF ALTERNATIVES

	Alternative 1	Alternative 1A	Alternative 2	Alternative 3	Alternative 4
	Pump to Falmouth for Treatment and Disposal	Pump Treated Wastewater to Falmouth for Disposal	Land Treatment at Otis	Biological Nutrient Removal at Otis	Pump Treated Wastewater to Northern Base Site for Disposal
Cost (present worth in millions)	$5.8	$5.2	$5.5	$5.2	$5.7
Groundwater Quality Improvements in Northeast Falmouth	No discharge at Otis	No discharge at Otis	Improvement, effluent dispersed	Improvement	No discharge at existing Otis site
Construction Impacts	Major, 7.5-mi force main and Falmouth WWTP	Major, 6-mile force main	Moderate, 75-acres disturbed	Minor	Moderate, 9.5-mi force main
Effect on Otis WWTP Operations During Construction	Minor	Minor	Minor	Major, phased construction required	Minor
Use of Existing Facilities at Otis WWTP	Insignificant use	Entire plant used except sand beds	Entire plant used except sand beds	Significant use	Entire plant used except sand beds
Operational Complexity	Simple	Slight modification of existing practice	Similar to existing WWTP	Complex	Slight modification of existing practice
Municipal Agreement Required	Yes	Yes	No	No	No
Further Groundwater/ Environmental Studies Required	Yes	Yes	No	No	Yes
Date Improvements would be Completed	mid-1991	mid-1991	mid-1989	late-1990	late-1990

TABLE 6-3

PROJECTED EFFLUENT CONCENTRATIONS

Constituent	Discharge Limitation	Existing WWTP	Alternative 1 Pump to Falmouth[1] for Treatment and Disposal	Alternative 1A Pump Treated[3] Wastewater to Falmouth for Disposal	Alternative 2 Land Treatment[2] at Otis	Alternative 3 Biological[3] Nutrient Removal at Otis	Alternative 4 Pump Treated Wastewater to Northern Base Site for Disposal
Flow, mgd	0.8	0.28	1.3+0.3 1.6	0.3	0.3	0.3	0.3
BOD, mg/L	30	14	0-5	<30	0-5	<30	<30
TSS, mg/L	30	12	0-5	<30	0	<30	<30
Settleable solids, ml/L	0.1	0	0	0	0	0	0
Total coliform bacteria, no./100 ml	1,000	>300,000	<1,000	<1,000	<1,000	<1,000	<1,000
pH (units)	6.5-8.5	6.5-7.5	6.5-7.5	6.5-7.5	6.5-7.5	6.5-7.5	6.5-7.5
Nitrate nitrogen as N, mg/L	10	2	10-20	20	0-5	<10	20
Total nitrogen as N, mg/L	10	18 TKN	10-20	20	0-5	<10	20
Oils and grease, mg/L	15	13.5	<15	<15	<15	<15	<15
Fluoride, mg/L	2.4	0.4	<1.0	<1.0	<1.0	<1.0	<1.0
Chlorine, mg/L[4]	1.0	0	-	1.0	1.0(5)	1.0	1.0
Boron, mg/L	20	0.5	<1.0	<1.0	<1.0	<1.0	<1.0
MBAS, mg/L	1.0	0.4	<1.0	<1.0	<1.0	<1.0	<1.0
Ammonia as N, mg/L	-	17	0	20	0	0	20
Total dissolved solids, mg/L	-	180	180	180	180	180	180
Chlorides, mg/L	-	35	35	35	35	35	35
Sodium, mg/L	-	40	40	40	40	40	40
Sulfate, mg/L	-	50	50	50	50	50	50
Total phosphorus as P, mg/L	-	8	0-2	8	0-2	<5	8

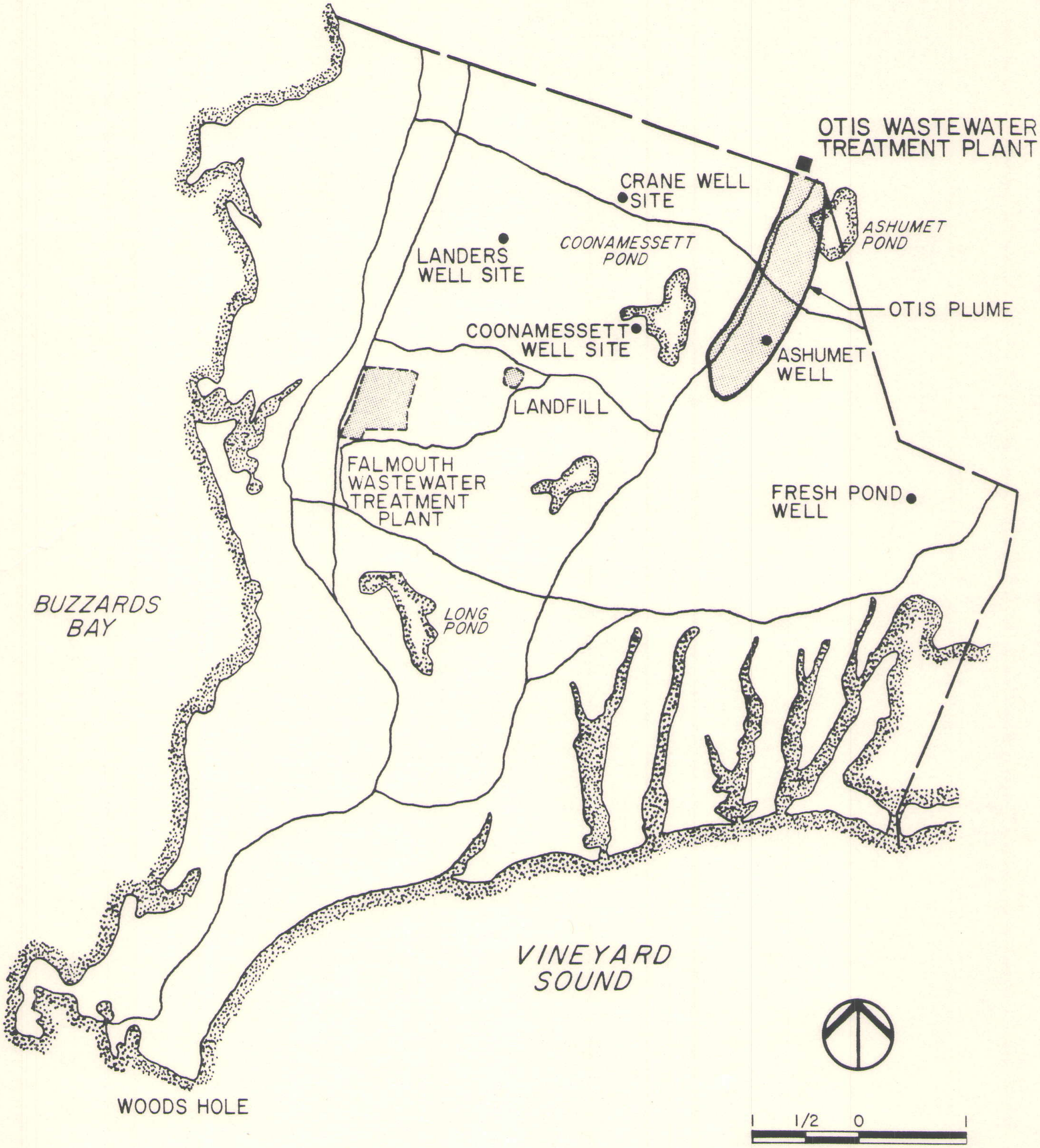
Notes:
(1) Effluent in monitoring wells located beneath rapid infiltration basins.
(2) Effluent in future monitoring wells located in irrigation area.
(3) Effluent before discharge to sand beds.
(4) Residual before discharge or irrigation.
(5) May have to be reduced to avoid vegetative toxicity.

projected to have different effluent concentrations and different discharge locations, their impacts on local groundwater vary. Figure 6-1 shows the location of the existing Otis discharge and existing and future municipal wells in Falmouth.

In Alternative 1 and 1A, the discharge site is moved to the Falmouth WWTP in West Falmouth. Therefore, groundwater quality will eventually improve in the area of the present Otis plume including the Town of Falmouth's Ashumet well. There may also be a potential positive water quality impact on Ashumet Pond, although this question is the subject of a current study.

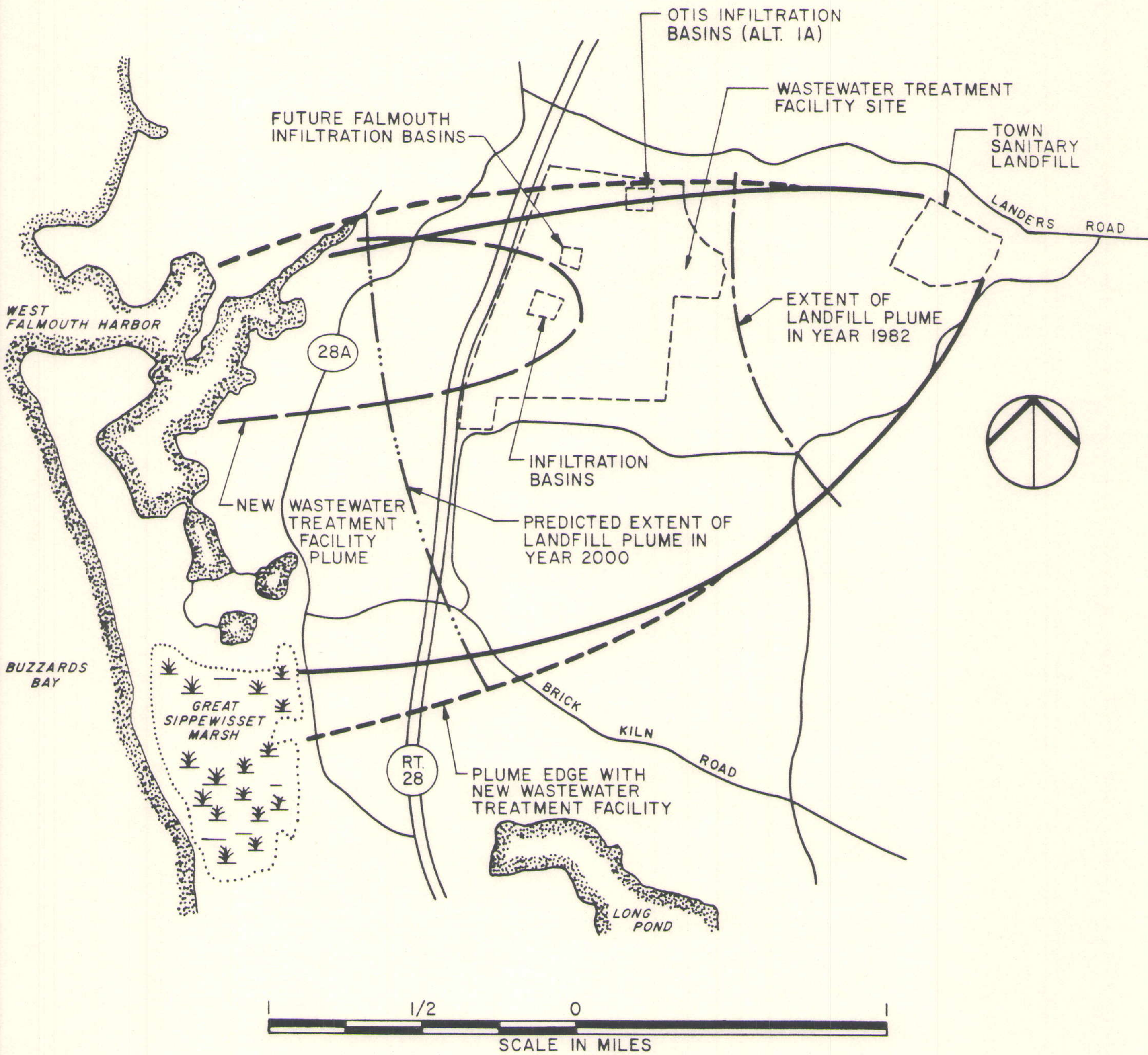
As shown in Figure 6-2, additional discharges in West Falmouth pose two questions: (1) What is the impact on the town's Class 3 area; and (2) what is the impact on Long Pond? Based on previous studies conducted by CDM, an area of degraded groundwater quality was predicted for West Falmouth with operation of the Falmouth WWTP. This is shown as the WWTP plume in Figure 6-2 and is the boundary of the Class 3 area. The Town of Falmouth was required to extend water mains to those residences having private wells. Construction of new infiltration basins for Alternative 1 or 1A will result in the Class 3 area being expanded to the north. The magnitude of the expansion can only be determined by further groundwater modeling efforts. There are some residences near the existing Class 3 area that may require municipal water.

Earlier modeling also showed that the existing landfill plume would be slightly deflected with the wastewater treatment plant discharge. Alternatives 1 and 1A both introduce up to an additional 0.3 mgd of effluent at the Falmouth WWTP site. The further deflection (if any) of the landfill plume can only be determined with additional groundwater modeling efforts. The landfill plume deflection question is critical because it affects the maximum rate of withdrawal for the Town of Falmouth's Long Pond Reservoir.



OTIS WASTEWATER TREATMENT EVALUATION

FIGURE 6-1 FALMOUTH GROUNDWATER RESOURCES



OTIS WASTEWATER TREATMENT EVALUATION

FIGURE 6-2 EXTENT OF LANDFILL PLUME SHOWING IMPACT OF NEW WASTEWATER TREATMENT FACILITY WITH GROUNDWATER DISCHARGE

For Alternative 2 groundwater quality in northeast Falmouth would improve compared to the existing situation because the land is an effective biological treatment and filter mechanism and the effluent is irrigated (dispersed) over a 60-acre area. However, some constituents will remain at high levels compared to typical potable groundwater quality (for example, TDS, sodium, chlorides and sulfate). This could impact water quality at a possible future town well at the Crane Reservation as shown in Figure 6-1.

For Alternative 3 groundwater quality will also improve in northeast Falmouth compared to the existing situation because the effluent will meet the State standards. There could be no certainty of re-establishing the closed Ashumet well, however, because groundwater travels at very low velocities. It may take 15-25 years for the Bardenpho effluent to reach the Ashumet well, and, as shown above, some constituents will likely remain at higher levels than desirable for good quality potable water. For both Alternatives 2 and 3, the possibility exists that future State discharge standards may impose higher levels of wastewater treatment.

For Alternative 4, groundwater quality will improve in northeast Falmouth because new sand filter beds will be located near the Cape Cod Canal at the point where the high-tension electric transmission lines cross the canal. However, in the area of the new sand filter beds groundwater quality will be degraded. The total new area affected would be about 25 acres of government-owned land.

6.2.3 CONSTRUCTION IMPACTS

Construction of Alternative 1 or 1A -- pumping to Falmouth -- will have a major impact on traffic and nearby residences along the force main route. For Alternative 1 ,a 7.5-mile, 12-in diameter force main would be constructed along Sandwich Road, Landers Road and Blacksmith Shop

Road to the Falmouth wastewater treatment plant. For Alternative 1A, a 6-mile, 12-in diameter force main would be constructed along Sandwich Road and either (1) along Route 151 and then cross-country to Landers Road and the Falmouth plant, or (2) continue on Sandwich Road then along Landers Road to the plant. This construction would have a duration of about one year and may require temporary traffic detours in some areas.

For Alternative 1, there would be significant additional construction-related impacts at the Falmouth wastewater treatment plant. Construction of additional aerated ponds for treatment would necessitate significant earth moving and may require relocation of some of the existing Falmouth irrigation facilities.

Construction of Alternative 2 would be entirely on-base and would impose only a moderate amount of inconvenience to base personnel and residents. An 11-acre storage lagoon and a 60-acre irrigation area would be constructed. However, these facilities would be located generally in areas of the base with minimal existing activity near the existing plant.

Construction of Alternative 3 would only impact the existing Otis WWTP site and should impose only minor inconvenience on base personnel and residences. The total area that would be disturbed is about two acres.

Construction of Alternative 4 will have a moderate impact on traffic and nearby residents along the 9.5-mile force main route. About two-thirds of the route would be located along a powerline right-of-way. Construction would be entirely within base property.

6.2.4 EFFECT ON OTIS WWTP OPERATIONS DURING CONSTRUCTION

Construction of a pumping station at the Otis plant under Alternative 1, 1A or 4 will have only a minor impact on plant operations. The facility will be a prefabricated concrete structure that can be sited to avoid interference with plant piping and facilities.

The impact on plant operations during construction of Alternative 2 is also expected to be minor. The effluent storage lagoon and pumping station would be constructed west of the existing Imhoff tank and the irrigation areas are outside the plant boundaries.

The effect of construction activities for Alternative 3 -- biological nutrient removal -- would be major. In fact, the construction period would be lengthened because staged construction is required to allow for converting both secondary clarifiers to aeration tanks. As the clarifiers are necessary for the proper operation of the existing trickling filter plant, one unit would be converted during construction of all other Bardenpho improvements, then the second unit would be converted after flow to the existing trickling filter plant is stopped. Other potential significant interruptions to plant operation could develop during removal of existing sludge transfer pumps and replacing them with return activated sludge and waste activated sludge pumps in the existing pump building. Placement of new yard piping, electrical and instrumentation equipment will likely place an additional burden on operation of the plant. Careful planning will be required to avoid deterioration of plant effluent that could lead to failure to meet the interim discharge standards.

6.2.5 OPERATIONAL COMPLEXITY

Alternative 1 -- pumping wastewater to Falmouth for treatment and disposal -- would be the simplest to operate. Plant operators already maintain several collection system pumping stations at the Base. The station will have an alarm system for pump failure, power outage, etc., so that only one operator is needed for daily checking of the station.

Alternative 1A or 4 -- treatment at Otis and pumping to another location for disposal -- would impose only a slight modification to existing practices. The operators' main function would still be operation of the plant. The pumping would be less troublesome than pumping in Alternative 1, because effluent (rather than raw wastewater) would be pumped, and flows would not fluctuate significantly.

Alternative 2 -- land treatment at Otis -- would be very similar in operation to Alternative 1A. The effluent pumping station operation would require daily adjustment of control valves to select the field to be irrigated. Otherwise, normal pump maintenance would be required.

Alternative 3 -- biological nutrient removal -- would be the most difficult alternative to operate and maintain. Compared to an activated sludge plant, the Bardenpho process requires only a few additional operational controls for more frequent analysis of dissolved oxygen and mixed liquor concentrations in aeration tanks. However, even an activated sludge plant requires far more operator training and process control adjustments than for the existing trickling filter plant. For example, the main control variable in the existing plant is the recirculation rate. Currently, one of three recirculation pumps is in use and has been for most of the time the rehabilitated plant has been on-line. With a relatively weak wastewater influent and a good final effluent, very few actual operator adjustments need to be made.

For an activated sludge type plant (or Bardenpho), however, adjustments must be made daily to consistently produce a good quality effluent. Daily decisions must be made regarding sludge recirculation rates and sludge wasting rates based on flow, temperature, mixed liquor volatile suspended solids, clarifier blanket depth, effluent concentrations and other factors. For this report, we have made the assumption that a qualified operator would be available to manage the facility. Nevertheless, the plant operation would be complex compared to other alternatives.

One alternative to staffing the plant with Base personnel would be to contract services to a private company. This option was not evaluated in this report, but could be considered in more detail if Alternative 3 is recommended.

6.2.6. MUNICIPAL AGREEMENTS

Alternatives 1 and 1A would require agreements with Falmouth. Alternatives 2, 3 and 4 would not require agreements. Under Alternative 1, wastewater from Otis would be treated and disposed at the Falmouth WWTP. This arrangement requires the most extensive agreement because both new capital costs and operating costs are incurred.

Among the issues to be resolved in an agreement with Falmouth are the method of capital cost and operation and maintenance cost apportionment, method of payment, cost accounting methods and audits and measurement, sampling and analysis of Otis wastewater.

Under Alternative 1A, treatment would take place at Otis and effluent would be pumped to the Falmouth site for disposal. As shown in Chapter 4, a separate sand infiltration bed disposal area in the northern part of the existing site would be utilized. The Falmouth WWTP would not be impacted, so some of the contract items would not apply. Falmouth might, however, impose other terms or costs for use or lease of the site.

6.2.7 FURTHER GROUNDWATER STUDIES REQUIRED

Alternatives 1 and 1A involve disposal of Otis wastewater effluent in West Falmouth. As discussed above, the discharge raises questions concerning the boundary of the Class 3 area and the potential impact on Long Pond. Groundwater modeling studies were used to determine the impact of the Falmouth plant on local groundwater. Similar studies would be undertaken to assess the impact with higher flows. This would involve recalibration of the existing model, a preliminary assessment of impacts and a determination of whether additional field work is required. Based on our previous efforts, an engineering cost of about $50,000 would be appropriate for this type of study. The project duration would be four to six months. If additional soil borings, wells

or groundwater quality tests are required, the cost of this field program would increase the total costs and the project duration would lengthen.

Based on discussions with State officials Alternative 1 and 1A would require filing of an Environmental Notification Form (ENF) and an Environmental Information Report (EIR). The scope of studies required for these efforts has not been established however, issues other than groundwater impacts may be included.

Alternatives 2 and 3 involve continued disposal at Otis with effluent achieving discharge permit standards. No additional groundwater studies are required and State officials report that an ENF and EIR are not required.

Alternative 4 involves discharge of secondary effluent to new sand filter beds near the Cape Cod Canal. The effluent will reach the natural groundwater 25 to 50 feet below the elevation of the beds and flow horizontally for about 500 feet to the Canal. The effluent quality in the groundwater will be similar to the concentrations shown for Alternative 1 in Table 6-3. After dilution with the tidal waters of the canal the impact is expected to be minimal.

However, it is anticipated that an ENF/EIR will be required. And groundwater studies sufficient to allow reclassification of the impacted groundwater to Class 3 will be required.

6.2.8 ABILITY TO MEET DISCHARGE PERMIT SCHEDULE

The September 1984 Groundwater Discharge Permit includes an implementation schedule. The schedule calls for submittal of a preliminary engineering report detailing improvements to the existing system necessary to meet the effluent standards by October 1, 1985. The schedule also calls for submittal of final plans and specifications for improvements by October 1, 1986.

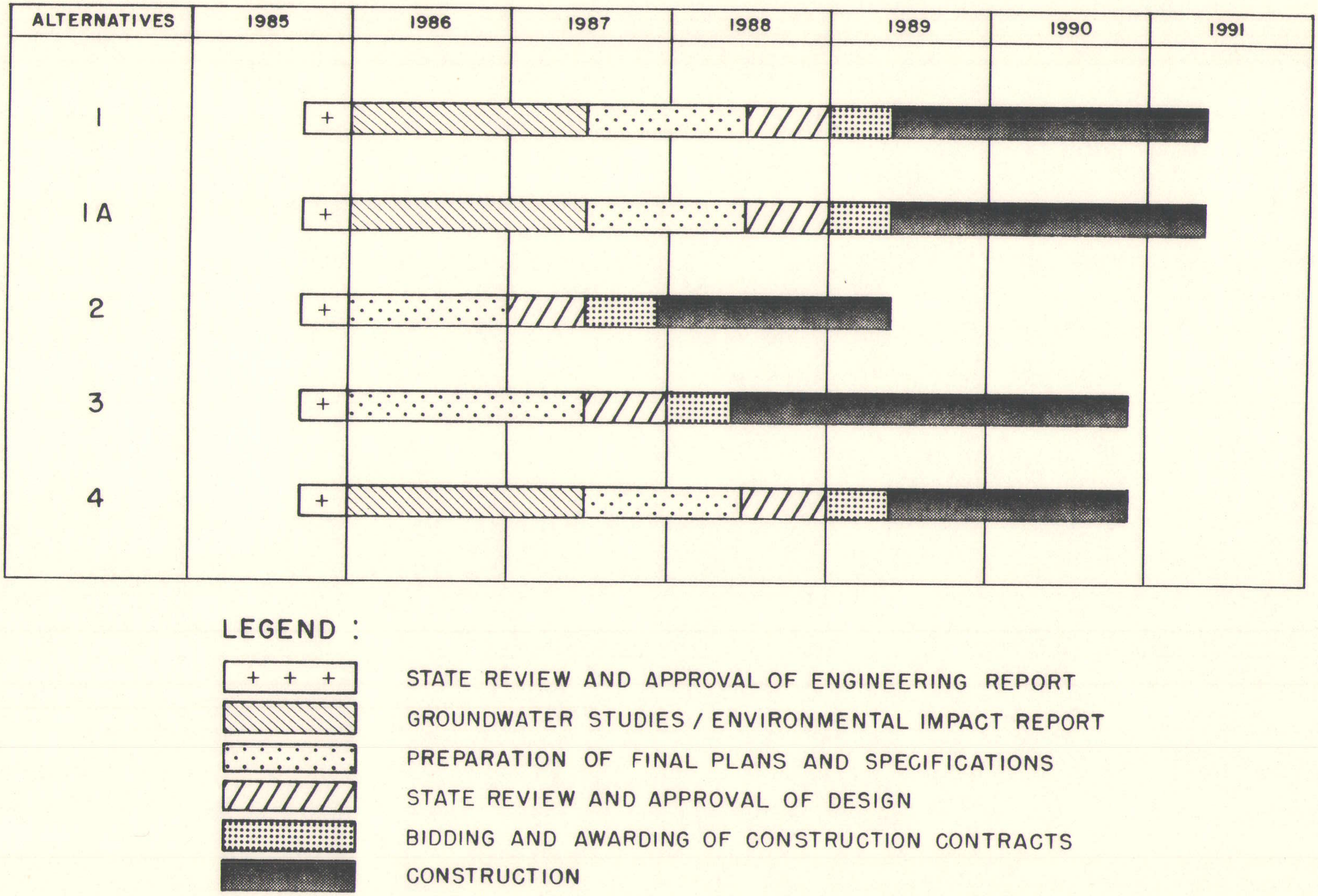
Figure 6-3 shows an implementation schedule for the five alternatives. All component durations are based on experience on other similar projects. So, the schedule should not be considered inflexible or final. In fact, until the State review period is completed (about 1 January 1986), the requirement and duration of additional groundwater and environmental studies for some alternatives cannot be determined.

For Alternative 1 and 1A -- pumping to Falmouth -- we have shown an environmental impact report requiring about 18 months to complete. The time could be shortened but the duration depends to a great deal on the level of public participation in the program. Since these alternatives are expected to be controversial and approval may require Falmouth Town Meeting Vote, 18 months is considered reasonable. AN ENF/EIR will probably be required for Alternative 4.

About 12 months would be required for final design of facilities except for Alternative 3 which may require up to 18 months. This additional time would be required since rehabilitation and conversion of the existing 40 year old trickling filter plant to the Bardenpho process is contemplated.

State review and approval of plans and specifications, the issuance of permits, prequalification of bidders, advertisement for competitive bidding, analysis of contractor bids and awarding of contracts normally requires about 11 months.

For Alternative 1 and 1A -- pumping to Falmouth -- the total construction period will take approximately 24 months. For Alternative 2 -- land treatment -- the construction period will be shorter (18 months) because all construction is on the base and equipment is not a major portion of the contract. Alternative 3 may take up to 36 months to be finished. As noted earlier, this alternative utilizes a good portion of the existing plant thus necessitating a staged construction program. Alternative 4 will require about 18 months for completion. Construction is located wholly within the Base property.



OTIS WASTEWATER TREATMENT EVALUATION

FIGURE 6-3 SCHEDULE FOR ALTERNATIVES

6.3 RECOMMENDATION

In the previous section, we compared the alternatives on the basis of nine factors covering cost, environmental and implementation issues. We found that since costs for all alternatives were within 15 percent that this factor alone should not be used for selecting a recommended plan. Comparing the other eight factors for the alternatives in Table 6-2 shows that no one alternative clearly is superior to others. All alternatives have their benefits and adverse consequences.

Therefore, we have selected the single issue which we believe overrides other considerations in selecting an alternative. That issue is groundwater quality. All alternatives discharge treated wastewater to the ground so water quality is impacted in some fashion. However, the degree of treatment before the treated wastewater mixes with native groundwater, and the location of the discharge varies among alternatives.

We believe that a long-term goal should be the restoration of groundwater quality in the northeast portion of Falmouth now impacted by the existing Otis plume. If the discharge at Otis is stopped the aquifer will naturally and eventually be restored. According to USGS researchers this process could take up to 30 years. Alternative 2 - land treatment - and Alternative 3 - advanced waste treatment would be located at Otis and would produce an effluent quality meeting the State discharge permit. However, groundwater quality would not improve to the same degree as if the discharge were stopped and the State may impose higher discharge standards in the future. This would require additional expenditures and for these reasons these alternatives should be eliminated from future consideration.

Alternatives 1, 1A and 4 all eliminate discharge at the present Otis site located about seven miles from the coastline. They all relocate the discharge from this existing inland site to sites near the coastline. Thus, these alternatives minimize area of groundwater impacted by the treated wastewater. In the case of Alternatives 1 and 1A with disposal in West Falmouth at the new Falmouth wastewater treatment plant, the Town has already taken action to reclassify the groundwater. The groundwater will have a Class 3 designation which means it cannot be used for potable purposes. The Class 3 area would undoubtedly have to be enlarged to accommodate the higher discharge rate including the Otis wastewater. The additional area would have to be determined by further groundwater modeling studies. These studies would also answer concerns regarding the Town's Long Pond water supply.

In the case of Alternative 4, the discharge would be relocated from the existing site at the southern end of the base to a location at the northern end of the base. The new site would be within several hundred feet of the Cape Cod Canal. No potable water supplies would be impacted by the discharge, however, a Class 3 groundwater designation would be required.

In selecting a recommended plan among Alternatives 1, 1A and 4, we believe that Alternative 1 - pumping wastewater to Falmouth for treatment and disposal - is the least desirable. The other two alternatives maintain the existing plant at Otis which has just been rehabilitated and which produces an effluent suitable for discharge to a Class 3 aquifer. Alternative 1 abandons the existing plant and requires the Town of Falmouth to significantly expand wastewater treatment facilities that are still under construction. Moreover, the additional Otis flows at Falmouth would be discharged about 1,000 ft further south than Alternative 1A. This would increase the potential for the plant discharge to impact Long Pond.

Both Alternative 1A and Alternative 4 are considered acceptable alternatives. Both alternatives maintain existing treatment facilities at Otis with discharge points relocated. Implementation of either would involve additional groundwater studies and application for new or expanded Class 3 area. For Falmouth, this would entail rerunning existing groundwater models at higher flow rates. For the northern base site new field work, collection of soil and groundwater information, and new groundwater modeling efforts would be required. In either case, the area impacted would be considerably less than the area presently impacted by the Otis plume.

Another major advantage of these alternatives over the other three alternatives is their ability to accommodate higher flows with minimal additional cost. As was noted in Chapter 3, no major base expansion is planned. However, if for any reason flow increased substantially, Alternatives 1, 2, and 3 would all have substantially increased costs. Alternatives 1A and 4 would not. This is because the pumping station and force main, which represent a major portion of the total costs, are already sized to accommodate higher flows. A certain minimum capacity is required to maintain self-scouring velocities in the force main. With lower flows, the pumping schedule is intermittent. With higher flows, the number of hours of pumping per day increases, but the physical size of pumps and force mains are not increased. Of course, the area of infiltration basins would be enlarged.

In deciding between the two alternatives, there are no major advantages of either. However, costs for Alternative 1A are about $600,000 less than costs for Alternative 4. This is because the force main to Falmouth would be a three and one-half miles less in distance than a force main to the northern base site. Unless some other issue emerges which shows the northern base site to be superior to the Falmouth site, the Falmouth alternative should be selected. This alternative will require agreement with Falmouth officials before it can be implemented. If significant opposition develops and the alternative cannot be implemented then Alternative 4 is a logical second choice. Either alternative will require additional studies and the filing of an EIR/ENF. So it will actually be some time before a definitive plan for Otis can be developed.